2nd World Irrigation Forum

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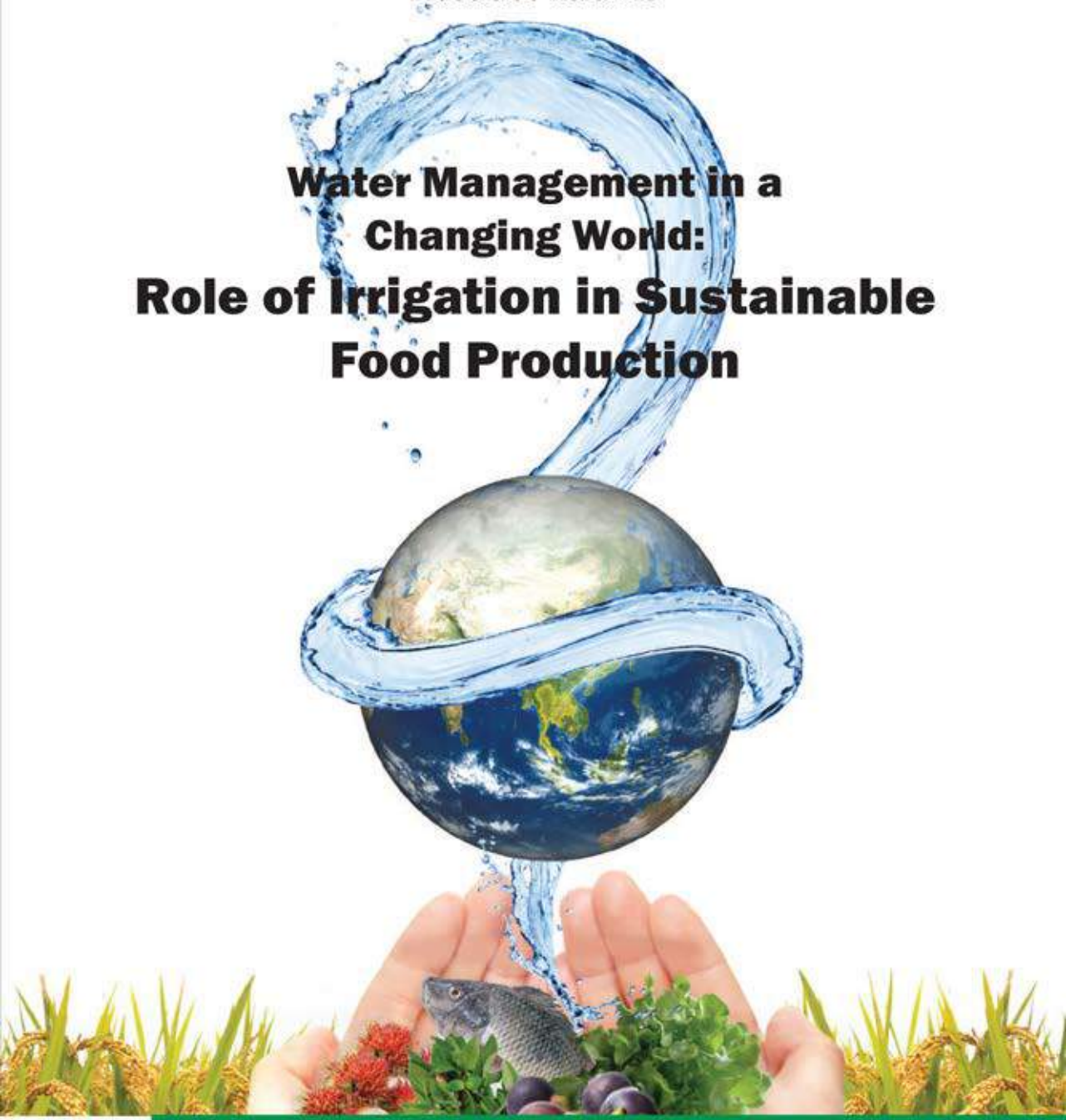
Abstract Volume



Water Management in a Changing World: Role of Irrigation in Sustainable Food Production

ICID•CIID

INTERNATIONAL COMMISSION ON IRRIGATION AND DRAINAGE

COMMISSION INTERNATIONALE DES IRRIGATIONS ET DU DRAINAGE

Water Management in a Changing World:

Role of Irrigation for Sustainable Food Production

International Commission on Irrigation and Drainage

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Organized by:

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International Commission on Irrigation and Drainage

Hosted by:

THAICID

Thai National Committee on Irrigation and Drainage (THAICID)

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The International Commission on Irrigation and Drainage (ICID), established in 1950 is the leading scientific, technical and not-for-profit Non-Governmental Organization (NGO). ICID, through its network of professionals spread across more than a hundred countries, has facilitated sharing of experiences and transfer of water management technology for over half-a-century. ICID supports capacity development, stimulates research and innovation and strives to promote policies and programs to enhance sustainable development of irrigated agriculture through a comprehensive water management framework.

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October 2016

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Dear Friends,

On behalf of THAICID, I am very pleased to welcome all members and distinguished participants to the 2nd World Irrigation Forum (WIF2) and 67th International Executive Council (IEC67) Meeting, organized at the International Convention and Exhibition Center Commemorating His Majesty's 7th Cycle Birthday Anniversary, Chiang Mai, Thailand from 6 to 12 November 2016.

It is apparent that Thailand is one of the ICID founder member and the leading countries that emphasize the significance of agriculture as well as water management. Earning its reputation as the kitchen of the world, the country has produced and distributed quality food to the world. Water, therefore, is considered an essential resource to ensure sustainable food production. In light of climate change and emerging environmental issues, national strategic plans have been formulated with particular attention given to food security, environmental preservation, water resources development and public participation.

Reflecting the key issues that have already been mentioned, this Forum features the theme of "Water Management in a Changing World: Role of Irrigation for Sustainable Food Production" with participants working in areas related to agriculture water management. The Forum thus offers an opportunity to connect, share experience and exchange opinions which would definitely contribute to further implementation and problem-solving activities.

Apart from this, being here in Thailand is truly a delight to enjoy tourist attractions including both natural and historical sites. Thailand is also distinguished with unique culinary, local products and traditional culture. Moreover, the hospitality of Thai people represents the country as the land of smile, leaving lasting impression to tourists worldwide. You will definitely enjoy your stay here!

Once again, thank you for your participation and attention. I strongly believe that this Forum is going to offer insight and valuable information which can be applied into practical use and fulfill the purposes of this event.

Sincerely Yours,

Sanchai Ketworrachai
President, THAICID

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Growing food security concerns due to demographic pressure, combined with increased competition for water and climate variability have once again brought forward the importance of irrigation for a stable and sustained growth in global food production. At the same time, the plight of the poorest of farmers is likely to be worsened under increasing climatic variability, endangering their food security. The 2030 Agenda for Sustainable Development Goals (SDGs) adopted by world leaders as a way forward to the 'Future we want' through SDG2: Zero Hunger and SDG6: Clean Water and Sanitation require collaborative efforts to ensure water and food security provides the foundation for all the 17 SDGs.

Recognizing that all these efforts require multi-disciplinary solutions through and in close collaboration with various institutions. ICID is bringing together all stakeholders involved in irrigation, drainage and flood management under the umbrella of World Irrigation Forum (WIF). In order to stimulate and promote irrigation, drainage and flood management among all stakeholders, ICID convenes WIFs with a view to:

- Support multi-disciplinary solutions for AWM in the 21st century;
- Share latest irrigation and drainage policies, innovations and technologies;
- Provide opportunities for developing collaboration among various national/ international institutions/organizations and private sectors entities working for irrigated agriculture;
- Explore and formulate concrete multi-disciplinary proposals; and
- Advocate political commitments for sustainable use of water for agriculture.

Accordingly, the International Executive Council of ICID in its 65th meeting at Gwangju, Korea (2014) decided to choose the main theme of the 2nd World Irrigation Forum as "Water management in a changing World: Role of Irrigation for Sustainable Food Production", which is further divided into three sub-themes.

ICID's triennial WIFs are the major events in the field of Agriculture Water Management where the experts from irrigation, drainage, flood management, agriculture and other allied subjects deliberate on emerging issues that arise out of a new experiences and look at future challenges.

The pre-Forum proceedings provided in your kit includes background papers and abstracts of papers with an electronic version containing all full length papers. I am confident that these proceedings will be useful to all delegates and many others beyond WIF2. Various stakeholders' perspective has been represented in these

papers. I am confident that this volume will help you in your active participation in various sessions.

Apart from the technical sessions there would be seventeen Side Events organized by various international partners, a Ministerial Roundtable, Senior Officers' Roundtable and Farmers Roundtable. The International Exhibition along with the WIF2 is sure to provide a rich experience providing multi-disciplinary perspective.

Dr. Saeed Nairizi
President, ICID

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Increasing demand of water for domestic, industry and nature has put pressure for more efficient use of water in agriculture through better irrigation and drainage management. Modernization of irrigation services, through upgrading existing infrastructure and improving irrigation management practices is a challenging task with technical, social, financial and institutional dimensions. Innovative solutions based on new management options and widely available technologies are needed.

Globally there have been changes in knowledge, skills, attitudes and policies regarding agricultural water management (AWM) and the environment. encompasses a range of options from rain fed farming to full irrigation. At the same time changes are taking place in attitudes and approaches followed by various actors involved in AWM.

Accordingly, WIF2, hosted by Thai National Committee of ICID (THAICID) and Royal Irrigation Department, is being organized in cooperation with and in partnership with AARDO, ADB, FAO, ICRISAT, IWMI, UNESCO-IHE, UNU-FLORES and many others International Partners during 6-8 November 2016 at Chiang Mai in Thailand. The main theme of WIF2 is “Water management in a changing world: Role of Irrigation for sustainable food production”.

Background papers on the three Sub-themes: 1. Key issues of irrigation and drainage in balancing water, food, energy and ecology; 2. Management of climatic extremes with focus on floods and droughts; and 3. Key and smart actions to alleviate hunger and poverty through irrigation and drainage are part of this publication. Experts representing various stakeholders with a view to present the global perspectives on these three sub-themes were commissioned to prepare background papers on each of the sub-theme. My special thanks are due to the Dr. Reza Ardaknian (UNU-FLORES), Prof Tsugihiro Watanabe (Japan) and Dr. Olcay Unver (FAO) and their teams for preparing these knowledge rich background papers.

More than 300 abstracts were received on various sub-themes, which were reviewed and finally 182 papers have been received. These papers will be presented during the Forum in several parallel sessions and poster sessions and the issues emerging from the sub-themes would be discussed in the plenary session and presented as conclusions and recommendations from WIF2. In order to facilitate the discussions during the various Forum sessions, this pre-Forum proceeding has been placed in your hands which includes the abstracts of all accepted papers/posters and a USB containing all the full length papers including the Background Papers of the sub-themes. Many other experts offered their valuable time at the request of the International Technical Advisory Committee (ITAC) to act as Reviewers of more

than 300 abstract presented. My profuse thanks are due to each member of the International Review Team for their time and efforts in reviewing the abstracts/papers.

Besides deliberating on the technical papers presented, the Forum provides opportunity for participation of policy makers, planners, famers, youth and the industry. Accordingly the Forum includes a Ministerial Roundtable apart from a Senior Officers' Roundtable and a Farmers' Roundtable, Side Events and International Exhibition.

Last but not the least, my special appreciation to the Central Office team consisting of Dr. Vijay K. Labhsetwar, Director, Mr. Madhu Mohanan, Communication Officer and Mr. Keshav Dev Tanwar, IT Assistant and other supporting staff for their dedication in bringing this volume to you on time. My special thanks are also due to Dr. A.K. Bhattacharya, an external expert, engaged in supporting the review process.

Avinash C. Tyagi
Secretary General, ICID

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The triennial World Irrigation Forum (WIF) aims to bring together all the stakeholders involved in irrigation of multi-disciplinary and all scales, including the policy makers, experts, research institutions, non-governmental organizations and farmers. It provide a platform for the world irrigation community and interested development professionals to find solutions to problems plaguing the irrigated agriculture, in time of depleting freshwater resources as a result of global warming and climate change.

ICID provides a unique platform for multi-stakeholder in World Irrigation Forum (WIF) for sharing and learning by engaging in issues of interest at global level. WIF also gathers a wide range of experts from various fields to discuss important issues highlighted.

The World Irrigation Forum stimulates and promotes multi- disciplinary discussions towards sustainable solution to water management in agriculture through:

- Exchange of latest irrigation and drainage policies, practices, innovations and technologies;
- Exploring and formulating concrete inter-disciplinary proposals;
- Development of liaison/ collaboration among various national / international institutions/ organizations/ private sector working for irrigated agriculture; and
- Advocacy for political commitments.

The First World Water Forum (WIF1) took place in September 2013 at Mardin, Turkey on the theme “Irrigation and Drainage in a Changing World: Challenges and Opportunities for Global Food Security” and was attended by over 700 participants drawn from different disciplines including young scholars, farmers, academicians, researchers, international scientific community, engineers, industry and the irrigation managers.

Summary Report available at **http://www.icid.org/wif1_sumreport.pdf**

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Water management in a changing world: Role of Irrigation for sustainable food production

The world's population is growing rapidly and is expected to reach about 9 billion by 2050, mostly living in urban areas, posing challenge in meeting the sharply growing water, food and energy demands. In order to feed this growing population it is estimated that agricultural production needs to be increased by about 70 % globally and by 100 % in developing countries. It is likely that increased food production will have to be achieved with a reducing share of water for agriculture due to competition from other sectors including uncertainty due to climate change and variability. This calls for growing more with less water in a sustainable manner. New ways to grow food in ecologically and ethically responsible manners and expansion of irrigation to previously rainfed areas, along with supply and demand side management options will play a significant role in achieving this goal.

The key to sustainable development of irrigated agriculture in the changing environment and the on-going rural transformation lies around modernization of irrigation systems and related services to improve water use efficiency, improving water and land productivity supported by financial mechanisms, reform of management institutions, adoption of efficient water management techniques including recycling and reuse of waste water, use of modern technologies, increasing awareness about water scarcity, capacity development of service providers and farmers etc. with participation of all the stakeholders (public and private sector, academic and research institutions, industry, civil society, farmers' and their organizations etc.).

In order to address these issues the World Irrigation Forum (WIF) that would include policy makers, experts, researchers, private sector companies (manufacturers, consultants, contractors), farmers, non-governmental organizations, among others, is being organised by the International Commission on Irrigation and Drainage (ICID) in cooperation with the host Thailand National Committee on Irrigation and Drainage (THAICID) and in partnership with a number of International institutions engaged in solving these issues.

Sub-themes and Topics:

With the main theme for the Forum, the issues are divided under following sub-themes and topics:

Sub-theme 1. Key issues of irrigation and drainage in balancing water, food, energy and ecology

Topics

1.1 Roles and efforts of the irrigation sector with respect to the World water issues

1.2 Drivers of policy, institutional, organisational and financial innovations for better stakeholder participation in irrigation and drainage services

1.3 Roles of water users, private sector, government organizations and civil society in management, operation and maintenance of irrigation and drainage systems

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Sub-theme 1. **Key issues of irrigation and drainage in balancing water, food, energy and ecology**

Dr. Reza Ardakanian (UNU-FLORES), Dr. Tamara Avellán (UNU-FLORES), Vice President Hon. Dr Hafied A. Gany (Indonesia), Vice President Hon. Dr. Willem Vlotman (Australia), Dr. Sylvain Perret (Chairman, WG-ENV, France), Vice President Hon. Dr. Ragab Ragab (UK), Ms. Hayati binti Zainal (ICID Young Professional, Malaysia), and Dr. Sangjun Im (Seoul National University, Korea)

Sub-theme 2. **Management of climatic extremes with focus on floods and droughts**

Prof. Tsugihiro Watanabe (Japan), Mr. Johannes Cullmann (WMO), Dr. Chandra S. Pathak (USA), Mr. Mika Turunen (Finland), Dr. Kamran Emami (Iran), Dr. Graziano Ghinassi (Italy), and Ms. Yasmin Siddiqi (ADB)

Sub-theme 3. **Key and smart actions to alleviate hunger and poverty through irrigation and drainage**

Dr. Olcay Unver (FAO), Ms. Robina Wahaj (FAO), Ms. Elisa Lorenzon (Italy), Mr. Kouresh Mohammedi (Canada), Mr. Jerome R. Osias (Philippines), VPH Felix Reinders (South Africa), Dr. Suhas Wani (ICRISAT), Ms. Jyotsana Chuchra (India), PH Peter Lee (UK), Dr. Sangjun Im (Korea)

Background papers

Sub-Theme 1
Key Issues of Irrigation and Drainage in Balancing Water, Food, Energy and Ecology

ABSTRACT

The great challenge for the coming decades will be to increase food production with fewer resources -water, soil, energy, and biodiversity. The effective and sustainable use of resources for agriculture has become a global priority of vital importance, requiring urgent and immediate solutions in view of intensifying competition. In order to foster sustainable development it is essential to maintain the balance between water, energy, food, and ecosystem services. However, there are a number of issues that the irrigation and drainage sector is facing in terms of (1) safeguarding resource availability and its quality when designing new systems, (2) the operation and maintenance of existing systems and in turn their impact on resources and the environments that hold them, and (3) the stakeholder interaction and participation that lead to the governance of the systems and their underlying resources. The future challenges require unconventional thinking and solutions. Increasing water supply to meet the future demand requires a more efficient water use, use of non-conventional water resources, and water harvesting. Thinking within the water-energy-ecosystem-food nexus framework with water resources at its heart is essential. Sustainability can only be achieved within a complete water chain approach and with full stakeholder involvement from start to end and from farmer to minister. We need to adopt a more integrated holistic approach to understand and sustainably manage resources with the aim to produce more from less “more crop per drop per kilowatt” without hampering natural ecosystem services.

1. Introduction

For a few decades already, and under acceleration in the new millennium, the world is facing unprecedented transitions which interact with water management at large and irrigation sector in particular. Some of those transitions are continuous and somewhat foreseeable: demography, urbanization, biodiversity loss and environmental degradation. Other changes are more sudden or difficult to predict: the economic slow-down in most developed and transition countries since 2008, the technology and communication revolution, health crises, conflicts, and massive migrations. All of the above phenomena contribute to deepen poverty and food insecurity in many least–developed areas.

Demography and urbanization especially have indirect yet massive effects on irrigated agriculture: food demand grows and changes towards diversified diets; the emerging middle-class demands healthier, safer, more “ethical” products; energy demand keeps increasing (hence competing with other water uses); even in least developed areas, the young migrate or show low interest in agriculture, resulting in the rise of youth unemployment issues.

Global water demand is largely influenced by population growth, urbanization, food and energy security policies, and macro-economic processes such as trade globalization and changing consumption patterns. The global water demand is projected to increase sharply by 55% in 2050 (WWAP 2015).

Agriculture accounts for 70 percent of total global freshwater withdrawals, which is as high as 90% in many regions of the developing world, making the agricultural sector the largest water consumer (FAO 2015).

Figure 1). Irrigation is of crucial importance to global food security. Irrigated crops account for 40% of global crop production while being cultivated on 20% of the global land surface

(FAO 2016). Yet, if 37% of arable land is irrigated in Asia, 14 and 5% of land is irrigated in Latin America and Africa respectively. Times of rapid expansion and massive investments in irrigation are of the past. Indeed, FAO projects that only a small amount of additional land will be equipped for irrigation by 2050. Compared to 48 and 53 million hectares of land equipped with irrigation in East Asia and South Asia respectively during 1961/63 – 2005/07, only 8 and 3 million hectares respectively are projected to be added by 2050 (FAO 2015). Irrigation water use will increasingly compete with natural ecosystems needs, and increasing urban and industrial demands, in a context of increased resource scarcity, and climatic changes.

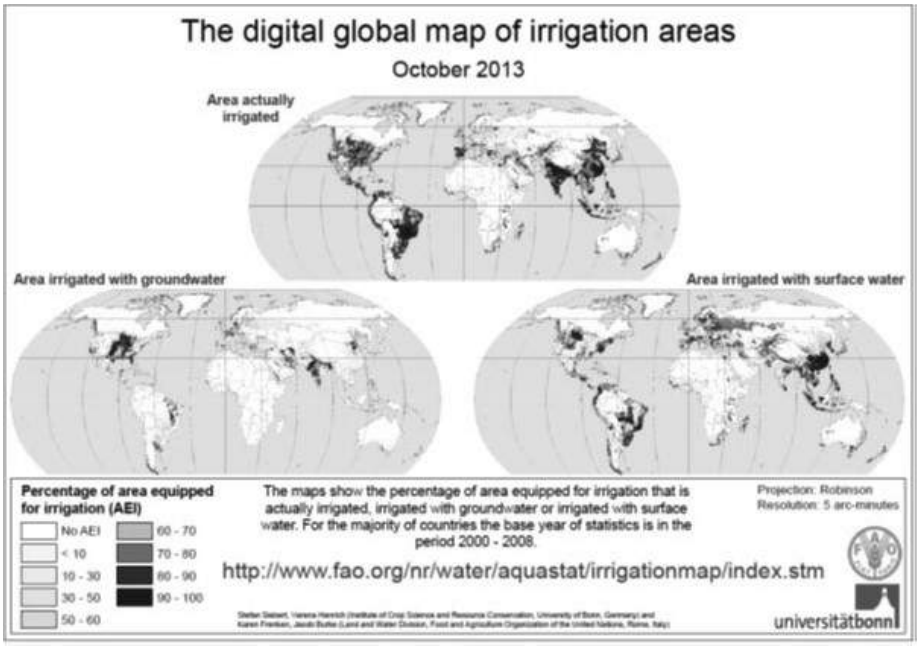

Figure 1. Global distribution of areas irrigated with groundwater and surface waters from "Stefan Siebert, Verena Henrich, Karen Frenken and Jacob Burke (2013). Global Map of Irrigation Areas version 5. Rheinische Friedrich-Wilhelms-University, Bonn, Germany / Food and Agriculture Organization of the United Nations, Rome, Italy"

Meanwhile, the food production and supply chain consumes about 30 percent of the total energy consumed globally (FAO 2011b). Energy is needed to produce, transport and distribute food as well as to extract, pump, lift, collect, distribute, transport and treat water. Conversely energy production from crops through biofuels and biogas is seen as a mitigation measure against increasing greenhouse gas emissions and as a CO2 neutral means of producing energy. Competition for soil and water for the production of food versus energy is an issue and will only increase in the near future as about 60 percent more food will needed to be produced by 2050 and energy demand is projected to grow by nearly one-third between 2013 and 2040 (OECD/IEA, 2015).

As a result total global water withdrawals for food crop irrigation are projected to increase about 10 percent by 2050 (FAO 2011a) and water withdrawals for energy production, which currently account for 15% of the world's total, are expected to increase by 20% by 2035. While the water is used for agricultural production, forestry and fishery, utilization also to produce or transport energy in different forms, and supply chain consumes about 30 percent of total

energy consumed globally (FAO, 2014). Biofuels offer an alternative energy source to fossil fuels. Their water-related impacts mainly depend on whether they are produced from rainfed or irrigated feedstock crops (Babel et al., 2012). The water requirements of biofuels produced from irrigated crops can be much larger than for fossil fuel resources and can therefore have important implications for local water availability (Gheewala et al., 2014), whereas rainfed production does not substantially alter the water cycle (WWAP, 2014).

Cities and the industry also claim increasingly more water, energy and land resources, and at the same time, face problems of environmental degradation and in some cases, resources scarcity (FAO, 2014). Cities import significant amounts of food, consumer goods and energy from outside the city, which requires large amounts of water at the point of production, transportation and sale. This virtual water footprint of cities greatly exceeds direct water use (Mekonnen & Hoekstra, 2016). Overall, since demand management approaches are to be favoured instead of supply-driven approaches, and that many sectors are concerned, IWRM is to be promoted further, and implemented in more systematic, radical, practical, adapted ways. IWRM now must be included in the Food-Energy-Water (WEF) Nexus, which reflects the imperative need to better understand the trade-offs in water-oriented thinking towards other resource use (Hülsmann & Ardakanian, 2014; Hoff, 2011), in the face of the newly set SDG (e.g. addressing hunger, poverty, food and energy insecurity).

This document provides an overview of the scope of the issues that are to be covered under Sub-theme 1 of the 2nd World Irrigation Forum (WIF2) “Key issues of irrigation and drainage in balancing water, food, energy and ecology”. Two further sub-themes have been agreed upon: Sub-theme 2 “Management of climatic extremes with focus on floods and droughts” and Sub-theme 3 “Key and smart action to alleviate hunger and poverty through irrigation and drainage”.

In this first sub-theme the conference expects to facilitate discussion on various related topics with respect to the following key issues:

1. Balancing the increasing demand of diverse sectors (food, energy, ecology – would add water supply and sanitation) against a limited water, land, energy and nutrient supply.
2. Minimizing the negative environmental effects of irrigation, and maximizing the provision of ecosystem services
3. Understanding the role of stakeholders in governing irrigation and drainage matters

2. Managing increasing resource demands from various sectors

Ambitious plans for large irrigation infrastructures exist, yet they are fraught with uncertainty and risks (climate change, droughts, declining groundwater resources, and salinization) and marked by past experiences of poor management and low productivity in developing countries. Recent analyses show that large, multipurpose dams in West Africa for example are no panacea. Irrigation efficiency and productivity remain low due to poor capacities, planning, land and governance issues. Globally, although resource development and mobilization remain crucial and feasible in few places, opportunities for further massive development seem unlikely in many countries, owing to financial issues. It is unlikely that further significant increases in abstraction of water for irrigation at reasonable costs are plausible without severe environmental or social disturbances in most countries.

As a consequence, supply-driven approaches must definitely leave room for demand management, use efficiency increases, optimized allocation of various resources, capacity

development and sound governance. Water resources are limited and per capita water availability is decreasing. Surface irrigation has poor field efficiency. More efficient water use systems such as drip and sprinkler systems are required to replace such traditional systems, where possible. Novel strategies informed by different types of datasets and integrated through numerical models can help save water. In this way, for instance deficit irrigation techniques can be placed in areas where they make the most sense in terms of costs, social acceptance, and ecological usefulness.

2.1 Improving Water Productivity – Smart infrastructure

Modernization and rehabilitation of irrigation systems refers to the improvement of existing irrigation systems that includes planning, cost sharing, institutional arrangements and resulting required operation and maintenance, capacity development, canal control systems and development with respects to automation of such systems; use of internet, mobile communication and remote monitoring; standardization and codes of practices.

The increased efficiencies have come in great part from the improved understanding of the energy physics of water which led to modern evapo-transpiration (ET) theory and ET-based crop irrigation scheduling. Many water conservation techniques were developed in the last half of the 20th century, including drip and micro irrigation, which has spread from hyper-xeric conditions to nearly every climate and rainfall environment where there is a need, for one reason or another, to conserve water.

Use of Information and Communications Technologies (ICTs) for AWM is underway even in remote developing areas of Asia and Africa, with applications on irrigation scheduling, cost recovery, markets or flood hazards. However, high cost and high capacities are required for ICT maintenance. Therefore, application of this new technologies should be based on a sound feasibility study as well as cost-benefit ratio, and appropriate selection of ICT system and also consideration on technical level of personnel as well as installation and maintenance cost. Durable and hardened ICT systems have to be installed (because the systems are operated outdoor), and reliable and error free system require for successful system operation. Similarly, smart systems for the provision of the necessary energy for the pumping and distribution systems have been initiated. Solar powered pumping and distribution systems have been tested in Canada leading to >30% water and energy savings.

2.2 Augmenting water supply – Using non-conventional water resources

Reuse of agricultural drainage water can augment the available water in many countries where fresh water is in short supply. In some cases, the drainage water has low salinity level as it is generated by excessive use of fresh water in surface irrigation (e.g. Egypt and Syria). However, in some other cases, the drainage water is saline. In such case, water is mixed with fresh water before irrigation or used in alternatively with fresh water. Saline/brackish ground water can be used to irrigate salt tolerant crops (e.g. quinoa and amaranth) under a proper management system.

A truly integrated approach is essential to encourage the increased use of poor quality water for irrigation, in order to both minimize drainage disposal problems and maximize the beneficial use of multiple water sources. Agricultural use of non-conventional water is more easily accepted and implemented in water-short areas where irrigation is already practiced. However, skills development, appropriate institutions and strong extension services are required. Participatory bottom up approach is a cornerstone issue governing success and/ or failure in any reuse irrigation project. Salt movement is intimately tied to water movement, and therefore salinity management is largely a function of water management in any irrigation

system. Sustainability and success of non-conventional water uses depends on sound implementation and management.

Globally over 80 % of wastewater worldwide is not collected or treated, and urban settlements are the main source of pollution (WWAP 2012). Urban areas are both producers and consumers of large amounts of wastewater. Untreated or partially treated wastewater is increasingly being used for irrigation and will become the sole water source for many farmers in Sub-Saharan Africa (WHO, 2006). Nutrients and organic matter from wastewater can improve soil fertility and reduce the need to apply artificial fertilizers. Farmers can therefore benefit through increased productivity and yields and faster growing cycles, while decreasing their needs for artificial fertilizers and additional water sources (UNEP, UN-HABITAT, GRID-Arendal, 2010) as long as they adhere to a set of guiding principles to protect themselves and their families from waste water irrigation induced health risks (Figure 2). In areas with receding groundwater levels, injection of reclaimed wastewater into these aquifers can also be an alternative to the direct irrigation on fields.

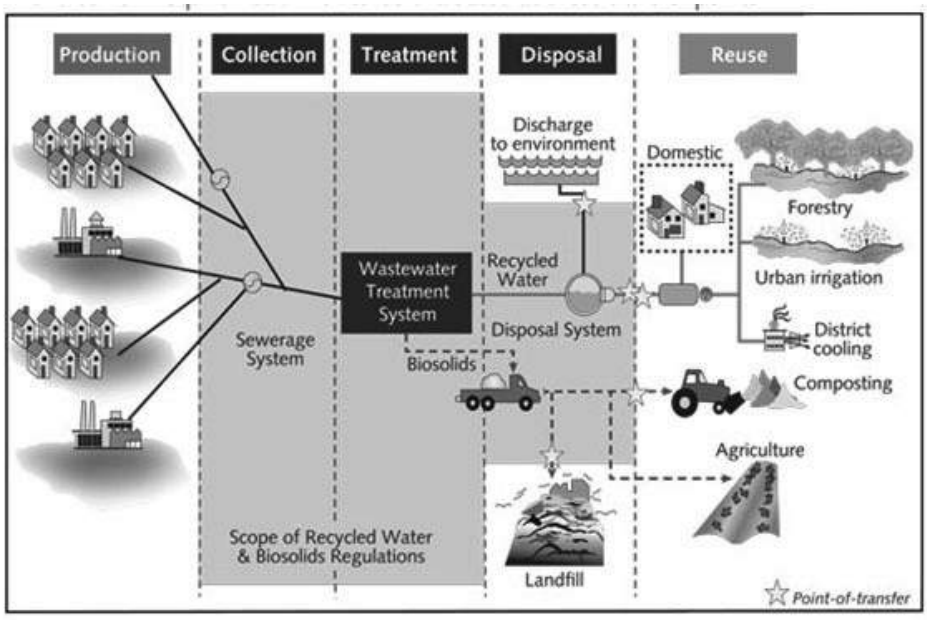

Figure 2. Schematic representation of the different aspects of wastewater re-use, including irrigation and the use of bio-solids as soil conditioner (from: Masdar Institute of Science and Technology, Abu Dhabi, UAE)

Over-exploitation of groundwater in coastal areas (in which half of the world's population lives) not only causes drops in levels but also leads to the deterioration of water quality due to salt water intrusion (Van Weert et al. 2009). Depleted groundwater storage for agricultural purposes results in increased costs for accessing the receding groundwater. It also produces significant negative impacts on the environment and functioning of the groundwater system, degrades the water quality and in the long term, exhausts the aquifer. Managed aquifer recharge (MAR) as a means to boost their natural supply is becoming increasingly important in groundwater management (Alley at al., 2002) and started to be a matter of interest even for European Union legislators.

De-salinization of sea water increases the total amount of available water. However, the de-salinization technology is still questionable with respect to its economic feasibility for agriculture. De-salinization industry, however, creates several adverse environmental impacts which require proper mitigation. These include discharge to the near-shore marine environment of reject hot brine, residual chlorine, trace metals, volatile liquid hydrocarbons, anti-foaming and anti-scaling agents.

2.3 Integrated modelling

Global models can already tell us where irrigation can be found (Siebert et al., 2013) and how global food markets influence the production of crops (Mauser et al. 2015). Dam managers calculate the energy production with models that take weather, energy prices and demand into account. Virtual water models can show us how water used for the production of crops is exported in the form of produce to other countries (Makennen and Hoekstra, 2016). Recent advances in life cycle assessment in irrigation allow for complete evaluation of environmental impacts and resources use (Payen et al. 2015). Models of different disciplines are increasingly interconnected (e.g. hydro-economic models, Divakar et al., 2013; techno-economic models, Ullah et al. 2015; techno-environmental models, Babel et al. 2012; agro-climatic models, Avellan et al. 2012) and contribute to quantifying IWRM-inspired measures, policies and alternative solutions. Advances in meteorological short- and long-term modelling may aid in adjusting the placement of infrastructure at climate-proof locations but also in the daily weather smart decision-systems of when, where and how much to irrigate to maximize yield and minimize water and energy losses (WMO, 2014). By linking models that describe water supply and water demand from the agricultural, the ecological, the energy production and the municipal perspective we can gain insight into trade-offs, needs and overlaps, and can try to minimize losses by identifying synergies. Areas where irrigation will make sustainable sense can then be identified more clearly, whereas those areas where water and energy demand will exceed the supply in the long run can be marked and alternative solutions sought (re-use of wastewater, de-salinization while using solar energy, etc.). Investments can then become much more targeted.

Questions on the increase of resource use efficiency:

- How can the use of smart infrastructure help in minimizing the impacts on the environment and affected population while maximizing the yields? What management and governance strategies need to be established to support this?
- How can the use of non-conventional water sources aid in conserving fresh-water sources? What impacts do these have on other resources such as soil and energy or on human health? What measures need to be put in place to safeguard environmental and human well-being?
- How can the integration of different modelling aspects inform decision-making at various levels, from global policies of where to irrigate, to local decisions of when to irrigate? Which mechanisms need to be in place to allow for this?

3. Minimizing the negative environmental effects of irrigation, and maximizing its positive effects and the provision of ecosystem services

Irrigation systems and related infrastructure closely interact with all three environmental compartments (water, soil, air). Such interactions refer to direct environmental impacts (e.g. emissions, pollutions, salinization, sodization). They also interact with riparian ecosystem and regional areas (e.g. hosting or threatening diverse biome and species, mitigating or amplifying floods, recycling nutrients) and offer a number of services to local community and societies at

large (e.g. micro climatic regulation, biomass production, specific products). Those interactions refer to ecosystem services.

3.1 Understanding the negative impacts

In some cases, human-built infrastructure can cause biodiversity loss and degradation of ecosystem services, yet it often directly depends on ecosystem services to maintain performance (WWAP 2015). Multipurpose dams can prevent nutrients and sediments from reaching oceans and alter the water cycle by increasing water 'residence time', altering the flow of matter, fish and energy in rivers which changes the conditions of these ecosystems entirely (Vörösmarty et al., 2010 in WWAP 2015). This can have a direct and negative impact on other sectors such as downstream wetlands, fisheries and agriculture. At the same time, dams only work effectively when supported by healthy ecosystems in order to avoid clogging, siltation, pollution, floods. In other cases, irrigated agriculture has, to some extent, also been proven to result in positive environmental effects. In particular, in arid to semi-arid areas field borders, canals, ditches, and reservoirs provide habitat expansion for a variety of wildlife (Jansen, M.E., 1997; Rhoades, 1997, in Sokja R.E., 2002).

Loss of productive capacity caused by soil salinization, sodification, and water logging, as well as runoff contamination, riparian habitat impairment, and species losses, high methane emissions by paddy fields, are often cited by critics of irrigation as evidence of fundamental drawbacks to irrigated agriculture. Surveys have indicated that of the existing irrigated lands, some 40-50 million ha show measurable degradation from water logging, salinization, and sodification (Rhoades, J.D., 1997 and Ghassemi, F.1995 in Sokja R.E., 2002). Erosion and sedimentation of reservoirs and channels cause failures of ancient irrigation schemes and limit the life expectancy of some modern dams to only a few decades as well (Reisner, M., 1986; Fukuda 1976 in Sokja RE, 2002). These problems demonstrate the need for intensified research and conservation, as well as improved dissemination and use of mitigating technologies. To support such actions, a wide range of methodologies are now available for assessing environmental impacts and quantifying ecosystem services in irrigation.

3.2 Maximizing positive effects

Ecosystem services of irrigation and drainage systems: Irrigation and drainage systems have long provided a number of ecosystem services that serve societies at large, in many dimensions. Those services are increasingly recognized and assessed (ICID, 2015). First, such services may be of supporting nature since irrigation systems host wildlife (birds, fish, biodiversity), and recycle nutrients. Second, provisioning services include food production (crops, fish, livestock), water supply to communities, fodder, fuelwood, medicinal resources. Third, irrigation systems regulate local climate, mitigate floods, and help purify water (regulating services). Fourth and finally, irrigation landscapes have socio-cultural and recreational values to many, including urbanites. These services have local, regional and global scope (e.g. when certain irrigation systems host endangered species or interact with climate). At the local level, the multi-functionality of irrigation systems is worth-mentioning, as they provide livelihoods, domestic and logistical services to communities, besides food production (e.g. boating and transport, domestic water supply, livestock watering, fishing, raw material collection, etc.). In South Africa, multi-functionality of small-scale gravity irrigation systems has been recognized and led to renewed, more inclusive and sustainable governance by local community, and ultimately to more efficient water uses (Perret, 2002).

Payment for ecosystem services (PES): Ecosystem valuation can be broadly described as what users would be willing to pay directly for the services, or what it would cost to replace the same services with built infrastructure (Boelee, 2011). Such valuations can be incorporated into national income accounts, or used to clarify comparative options in land use planning, payment

for ecosystem services and common asset trusts (Costanza et al., 2014). Valuations help in building the case for a green economy in the post-2015 development agenda. New contractual relationships between societies and irrigators may lead to payment for environmental services all the same. Measures are already put in place in Thailand to compensate rice farmers for accepting additional water in their paddy fields for flood mitigation.

The Water-Food-Energy (WEF) Nexus: The future challenges require unconventional thinking and solutions. Increasing pressures on environmental resources may undermine the resilience of ecosystems, limit economic growth and threaten goals related to human well-being including water, food and energy security (Hoff, 2011; Ringler and others, 2013). The WEF nexus links multiple resource-use practices and focuses on the efficiency of the system rather than on the productivity of isolated sectors (Hoff, 2011). Thinking within the water-energy-food nexus framework with the water resources at its heart is essential (Vlotman and Ballard 2014). We need to adopt a more integrated holistic approach to manage the water resources with the aim to produce more from less "more crop per drop per kilowatt" and involve stakeholders from farmer to minister.

Questions on understanding the effects of irrigation and drainage systems on the environment:

- How can the negative impacts be assessed objectively and measures be taken to mitigate or avoid these? What systems are needed for this?
- How can ecosystem services and multi-functionality of irrigation and drainages systems be assessed objectively? How can systems for payment for ecosystem services be implemented? Which mechanisms need to be in place to allow for this?

4. The role of stakeholders in governing irrigation

The role of stakeholders in governing irrigation, or in governing water management systems that includes drainage needed for water logging and salinity control is complex and will be different in each country. However it is not so much that we need to describe the role of stakeholders in water management systems, but more importantly we need to find out what they consider that their role is, or should be, and should not be.

Examples of the complexity of the institutional arrangements of irrigation and drainage management were formulated when modernization of systems was considered. For instance the modernization of irrigation and drainage is a highly interdisciplinary matter with institutional and organizational aspects that require a number of prerequisites including: sustainable operation and maintenance of irrigation and drainage systems; certainties on water regulatory authorities, land priority questions, water rights and financing of operation and maintenance; certainty of roles responsibilities and requirement for sustainable Water Users Association (WUA); appropriate water accounting and auditing at various levels of irrigation and drainage systems; effective irrigation/drainage management transfers (IDMT), including legislation and institutional requirements; effective Public Private Partnerships (PPP) in irrigation and drainage implementation. In order to start the process of stakeholder involvement the following should be considered:

- Carry-out an assessment of existing institutional arrangements with all stakeholders
- Ask stakeholders what needs to be established in order to become more involved (gap analysis)
- Identify the challenge & demand of the stakeholders

- Identify the need for continuity of participation and support capacity building
- Identify the need for political commitment, innovation and advocacy for involvement.

4.1 Active stakeholder involvement in policy and planning

Engagement with policy and planning activities requires in most cases first a top down approach where by the powers in place show a willingness to involve their target population in decision making. Secondly the population also needs to show an interest in being involved in policy and planning. For this to happen the state of development of the population needs to be assessed. The population includes farmers, the irrigators, the tertiary water management organisation such as Water User Associations, and all levels of government up to the minister. From this a gap analysis can be performed and a development plan initiated.

In other words as mentioned above to achieve active stakeholder involvement a planned process will need to be executed that involves:

- Assessment of state of institutional development at all levels;
- Needs assessment;
- Plan development reflecting:
    - Who you will engage with;
    - Why you will engage them;
    - Why they will want to engage with you;
    - How you will engage them;
    - When you will engage them, and how you will monitor and evaluate your engagement approach?

4.2 Incentives

The key for involvement of stakeholders in irrigation operation, management and maintenance (OMM) is the central question “what is in it for me?” Incentives do not necessarily need to be economic in nature. They can be improvement in lifestyle, improvements in physical environment and in general improvement in social well-being. Hence, in order to involve stakeholders in irrigation and drainage management it is essential to find out first in what type of environment they operate and what their needs are, not just involvement in irrigation but considering all aspects of being a successful irrigator. All stakeholders from farmer to system operator to top level regional and national government staff need to have a clear understanding of the potential benefits of being involved and they need assurance that those benefits are sustainable. Stakeholder engagement is a planned process with the specific purpose of working across organisations, stakeholders and communities to shape the decisions and actions of the members of the community, the stakeholders and the organisations involved. Typical questions to be asked in planning for the involvement of water managers at all levels, including foremost farmers, are:

- What issues do you face in being successful in your (water operation, management and maintenance) enterprise/organisation?
- Do you consider ecological aspects in your day to day operations?

4.3 Capacity Development

Capacity development in water management is teaching and training stakeholders in matters they should know to be able to distribute, use and dispose of water more effectively and efficiently at the lowest cost and least environmental impact. In fact it is not an environmental

impact; rather knowledge of the ecologies upstream of-, at location of- and downstream of water management systems is essential in a water-energy-food nexus approach to food production that espouses the sustainability principle. Triple bottom line elements should be considered; i.e. environment, people and economics. Precursor to capacity development should be a needs assessment; what arrangements are already in place and which are not.

There are at least five integrated aspects that must be examined to assess the institutional arrangements of Irrigation and Drainage management. These are among others: Availability of "Human Resources" for conducting effective function of irrigation and drainage infrastructures; Effective "Institution & Organization" to secure interagency working relationship; Availability of "appropriate technology" for sustainable O&M irrigation and drainage schemes; Sustainable "budget allocation" for conducting effective O&M; Effective "Regulatory Instrument" and Subsequent Enforcement.

Questions to be raised include:

- What is the level of current training and knowledge of the stakeholders
- What capacity development tools are currently available
- What is the awareness of stakeholders of existing and new know-how in the field of water management;

Questions on understanding the role of stakeholders:

- Who are the stakeholders and what interests do they have? What level of capacity do they currently have; what level is needed for their day-to-day work?
- What mechanisms need to be in place to be able to reach the various stakeholders? What systems are needed to reach them, to teach them, to provide them with incentives to safeguard the environment and society at large?

5. Conclusions and future outlook

The great challenge for the coming decades will be to increase food production with less water, particularly in countries with limited water and land resources. The effective and sustainable use of water for agriculture has become a global priority of vital importance, requiring urgent and immediate solutions in view of intensifying competition. However, it is critical that the ecology upstream of -, within- and downstream of an irrigation and drainage management system is considered at the same time. Sustainability can only be achieved with a complete water chain approach and with full stakeholder involvement from start to end and from farmer to minister.

Future increases in irrigated area will likely come mainly from the development of supplemental irrigation in humid rain fed areas, from improvements in (1) water use efficiencies associated with the utilization of existing irrigation resources in a smart way, (2) in the use of non-conventional water sources such as the reuse of municipal, industrial and agricultural wastewaters, and (3) the integration of modelling across different disciplines to better plan irrigation schemes at various spatio-temporal scales.

Balancing irrigation needs against environmental needs can be challenging. A paradigm shift towards the multi-functionality of irrigation systems can help in overcoming the negative impacts of poorly managed schemes. Approaches that view irrigation and drainage structures as suppliers of ecosystem services and require payment for them can be embedded in the

Water-Energy-Food Nexus, thus opening discussion about resources beyond just water. At the same time, strategies to avoid negative impacts such as over-abstraction of fresh water or salinization of soils need to be stepped up, and mechanisms for discontinuing existing mal-functioning systems be implemented.

Stakeholder involvement and capacity development rather than infrastructure should be the central focus of resource management. Considerable attention has been paid to describing who, what, where and how of stakeholder engagement. Capacity development is an important aspect of stakeholder engagement but is only one element in a much more complex process of stakeholder engagement. New in this engagement is the broadened scope when considering the water-energy-food nexus in relation with the ecologies upstream of water management system, within the system and downstream of the system. It is not just the environmental impact but it is the integration of ecology, and consideration of the ecological water needs, both in terms of quantity and quality, in the resource management chain.

The irrigation and drainage community has come a long way from designing large infrastructure projects all the way to valuing schemes that integrate into the landscape, provide eco-system services and are considered part of the cultural heritage of civilization. Nonetheless, many questions about the integration of different resource needs and balancing the trade-offs remain open. Under this sub-theme we expect to obtain some answers to the questions raised throughout the text.

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Sub-Theme 2
Management of Climatic Extremes with Focus on Floods and Droughts

ABSTRACT

The climate change is recognized as one of the most serious and urgent issue for human society and global environment. In the context of agriculture, improving irrigation and drainage systems and rural development will play a key role in achieving the rural water and food security under impending climate change, especially in the developing countries. This is a common understanding in the world irrigation and drainage community including the ICID.

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes, and can result in unprecedented extremes. These climate extremes pose significant impacts on human and ecological systems, which are influenced by changes in climate, vulnerability and exposure, resulting in increased fatalities and economic losses especially in developing countries.

To reduce the disaster risks, the global and local society or community need to assess the weather and climate events with their magnitudes, frequencies, and variabilities; the exposure of the society for these events; and the vulnerability of the region and society to these extremes. Even while the current local hydrological regime are being modelled with high reliability, the future projection of events and their impacts are expected to be more uncertain. Under the given uncertainties in climate change impact projections, improving resilience by reinforcing the capability of societies to better cope with the extreme events is one of the most favoured approach. The adaptation includes the practical measures that not only reduce the disaster risk but also reinforce the base system.

This paper aims at summarizing the current practices of managing extreme climate events, assessment of impact under the climate change scenario, and development of adaptation strategy under the recently adopted sustainable development Agenda 2030.

1. Introduction

The climate change is recognized as one of the most serious and urgent issue for human society and global environment. A recent report by the World Bank finds that the most severe impact of a changing climate would be the effect on water supplies. The report suggested that by 2050, an inadequate supply of water could knock down economic growth in some parts of the world a figure as high as 6 percent of GDP, “sending them into sustained negative growth.” Regions facing this risk can at least partly be averted by better water management (World Bank Group, 2016).

Climate change hits water supplies in multiple ways. Warm temperatures can cause more evaporation of water from landscapes, while changes in precipitation can lead to both more intense individual downpours but also swings into drought conditions. The human activity that consumes the most water is agriculture. In the context of agriculture, International Commission on Irrigation and Drainage (ICID) believes that improving irrigation and drainage systems building rural resilience will play a key role in achieving the rural water and food security under impending climate change, especially in the developing countries.

Irrigation and drainage are fundamentally the human activity to manage the variability or fluctuation of natural hydrological regime for better agricultural production. They have been continuously developed to function to adapt climate variability and change to some extent. Then, the current problem is on “extreme events” beyond the threshold or expectation. The challenges due to the climate change should be considered as another driving force to improve the irrigation and drainage system.

Accordingly, ICID deliberated on the theme "Securing Water for Food and Rural Community under Climate Change" at its 22nd Congress held in Gwangju, Republic of Korea, in September 2014. Two Congress Questions raised included one that is directly related to climate change was "How Irrigation and Drainage play an important role in Climate Change Adaptation?"

Discussions during the Congress highlighted that the climate change needs to be recognized as an added stress on the increasingly uncertain complex and interlinked issues of rural development and food security under demographic changes due to environmental concerns and limiting natural resources. Intervention to mitigate the impacts of climate change and consequent extreme climate events, such as floods and drought, must therefore be considered in the entire decision making processes in the irrigation and drainage activities (ICID, 2014).

A changing climate leads to changes in the frequency, intensity, spatial extent, duration, and timing of weather and climate extremes. These climate extremes pose significant impacts on human and ecological systems, which are influenced by changes in climate, vulnerability and exposure, resulting in increased fatalities and economic losses especially in developing countries. Increasing exposure of people and economic assets to the climate extremes has been the major cause of long-term increases in economic losses from weather- and climate-related disasters. Extreme events have greater impacts on sectors with closer links to climate, such as water, agriculture and food security, forestry, health, and tourism. As the general findings and outcomes, it was reiterated that intervention to mitigate the impacts of climate change and consequent extreme climate events have to be factored in all irrigation and drainage related decision making processes (Watanabe, 2016).

Based on these recognitions and discussion history on climate change and consequent extreme events, one of the sub-themes adopted for WIF2 is 'Management of climatic extremes with focus on floods and droughts' to facilitate discussion on various related topics such as adaptation of design and operation criteria for irrigation and drainage schemes in light of climate change impacts; managing impacts of extreme events – floods and droughts; dealing with climate change impacts on food security; regional water management. This Background Paper presents the framework of the expected discussion and information exchange on the sub-theme No.2, including the current world context, the development of impact assessment and adaptation strategy, and the challenges for managing extreme events on floods and droughts, with some introduction of past approaches and outcomes as well as state-of-the-art technologies.

2. Global Climate, Extremes and Agriculture

The latest IPCC report indicates once again, that future climate will depend on the combined influence of warming caused by already emitted green-house gasses, as well as future emissions on one hand and the natural climate variability on the other. A current analysis of green-house gas emissions shows (WMO, 2015) that, based on our current understanding of global warming mechanisms, humanity can continue to emit 12 to 15 years at current rate to surpass the threshold that marks the two degree warning at the end of the century with 0.66 probability.

Although a higher mean annual temperature, in combination with an increased CO2 level will have a positive impact on crop yields in parts of the world, in general climate change will have negative impacts on the production of major traditional food crops. Additionally, farmers remain concerned about an increasing intensity of extreme weather events that will occur as a result of climate change. Weather related events which have impact on agriculture include are:

(i) more frequent heatwaves,
(ii) erratic rainfall,

(iii) prolonged drought,
(iv) more intensive rainfall spells,
(v) increased winter storms and hurricanes, and
(vi) rising sea level and increased salinization

The IPCC fifth assessment report (IPCC, 2014) gives the following global data for the impacts of climate change on the yield of main crops (in %):

Irrigated Maize: - 4 to -7,	Rainfed Maize: -2 to -12
Irrigated Rice: - 9.5 to - 12,	Rainfed Rice: - 1 to +0.07
Irrigated Wheat: - 10 to - 13,	Rainfed Wheat: - 4 to -10

The extreme events will increase the vulnerability of food production and affect natural resources such as soil fertility; availability of water resulting in water stress; land degradation and desertification. Changing weather patterns, manifesting in changes in average temperatures and rainfall, will make it increasingly difficult to plan for activities such as sowing, planting, fertilizing and spraying. Rain-fed agriculture is especially vulnerable to changing weather patterns and the impacts of variable water availability. Some regions will experience excess water resulting in flooding and others will experience severe water scarcity. Annual average river runoff and water availability are projected to increase by 10 to 40 % at high latitudes and in some wet tropical areas, and decrease by 10 to 30 % over some dry regions at mid-latitudes and in the dry tropics.

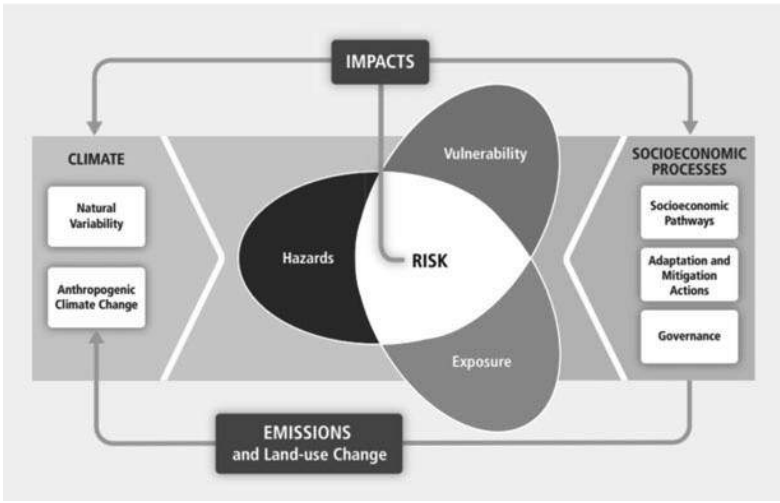

Figure 1. Risk of climate-related impacts results from the interaction of climate-related hazards with the vulnerability and exposure of human and natural systems (IPCC, 2014)

The changes in the hydrological regime would be a matter of great concern of agriculture and rural society. Not only at the farm level, climate change and consequents extreme floods and droughts will affect the agriculture systems at the basin level. The IPCC Fifth Assessment Report stresses that major future rural impacts are expected through impacts on water availability and supply, food security, and agricultural incomes, including shifts in production areas of food and non-food crops across the world. These impacts are expected to disproportionately affect the welfare of the poor in rural areas, such as female-headed

households and those with limited access to land, modern agricultural inputs, infrastructure, and education.

The risk of extreme events on the agriculture (or for that matter any socio-economic activity) is not only caused by the magnitude and extent of the hazard, like the duration of flood and drought, but is also governed by the exposure to the hazard and the vulnerability of the system to that event. In this context, "vulnerability means the propensity or predisposition to be adversely affected. Vulnerability encompasses a variety of concepts and elements including sensitivity or susceptibility to harm and lack of capacity to cope and adapt." And, the exposure means "the presence of people, livelihoods, species or ecosystems, environmental functions, services, and resources, infrastructure, or economic, social, or cultural assets in places and settings that could be adversely affected."

These recognitions on the risk and impacts of climate change and consequent events are now becoming common in the global society. When we think the extreme flood and drought as the results of the climate change, this framework is to be essential. The impacts are subject to the special and temporal scale of flood and drought, the function and potential of water management system in the rural society and crops, farmland, infrastructures as well as farmers and people in the rural area. In a point of view of irrigation and drainage management, which is recognized as adaptation with mitigation actions, the assessments of the local structure on the risk of extremes of flood and drought is to be the base for its improvement under changing climate.

3. Development of Impact Assessment and Adaptation Strategy

In order to reduce impact due to these climate extremes it is essential to develop strategies for disaster risk management in the context of climate change which may include coping and adaptation mechanism, informed by and customized to specific local circumstances. Adaptation to climate change and disaster risk management provide a range of complementary approaches. An iterative process of monitoring, research, evaluation, learning, and innovation can reduce disaster risk and promote adaptive management in the context of climate extremes.

While we have been integrating local knowledge with additional scientific and technical knowledge, which can improve disaster risk reduction and climate change adaptation, however, lack of sufficient scientific knowledge to better understand what is going on and what can be predicted in climate change with reasonable accuracy. Meanwhile, we cannot wait until understandings of the future climate change is clear and its impacts are known. It is therefore necessary to factor known impacts of climate change in all processes of planning, design, implementation, operation, maintenance and management of the irrigation and drainage activities.

3.1 Development of Impact Assessment

The climate extremes can result in droughts and floods due to an accumulation of weather or climate events and may not be caused by a single individual extreme event.

Evidence of the impacts of climate change on sea level rise, change of frequency and severity of tropical cyclones or extreme water-related disasters, and prolonged drought periods are being studied by the scientists all over the world. To understand, how climate change will influence over the long-term the risk landscape that governments, businesses and citizens need to prepare for, it needs to be weighed against other major trends influencing our exposure to these hazards and threats and our capacities to deal with them. Climate change is expected to influence other risk factors beyond natural hazards themselves. Water, food, and energy security could be affected in a number of regions or countries, making these areas

more vulnerable to hazards and threats, affecting their economic development, the well-being of their citizens and eventually their stability, which could lead to undesirable impacts on humanity.

There are many interconnected climate risks such as prolonged droughts increase the risks of forest fires. Droughts can also lead to more catastrophic floods when water management practices adapt to the trend of reduced water resources without considering that high flows still can reach highest levels. Brisbane floods in Australia in 2011 and UK floods in winter 2013 followed prolonged drought periods. Droughts impact also aquifers whose depletion can affect soil stabilities, leading to subsidence in urban areas and reduced structural resilience to earthquakes.

Thus, these climate extremes have significant impact on earth's environment. Extreme events have greater impacts on many elements of the environment and human systems including such as water, ecology, sedimentation, forestry, flora and fauna, and human health. Impact from climate extremes on environment are mostly observed at the watershed level. Whereas, impacts on human system are experienced at the regional and local level.

In order to understand and determine qualitative and quantitative impact of climate extreme over short-term (5-10 years) and long-term (10 to 50 years), impact assessment needs to be developed on the environmental and human systems. Impact assessment for environmental system could include rainfall, snowpack, evapotranspiration, natural and man-made surface water storage, surface water flow, groundwater storage and recharge as well as other elements. These assessments need to be completed and are expected at regional or watershed level.

Studies indicate that gross irrigation water requirements may increase or decrease depending on the future efficiency of irrigation and conveyance systems, the effect of population growth on food (and water) demand and the climate change impacts, while the first two seem to have the strongest influence Fader et al (2016). The Mediterranean area as a whole may require an increased gross irrigation between 4 and 18% due to climate change alone. Population growth increases these numbers to 22 and 74 %, respectively.

Studies show that the changes in projected future peak flows due to snow melt fall outside the range of natural variability compared with current natural variability in southern Britain than in the north (Bell et al, 2016). In a recent research (Clark et al, 2016) on important sources of uncertainty, it has been reported that these are commonly neglected by the water management community, especially, uncertainties associated with internal climate system variability, and hydrologic modelling. It also articulated issues with widely used climate downscaling methods.

Studies on the effects of climate change on groundwater recharge of the upper Tiber River basin in central Italy (Behulu et al, 2016) presented summaries and overview of several climate change studies over the Italian territory. Specifically, it presented study on a calibrated and validated SWAT watershed model that used the climate model outputs obtained from three dynamically downscaled regional climate models in order to evaluate the groundwater recharge characteristics of the basin.

A review of existing multi-risk assessment concepts and tools applied by organizations and projects providing the basis for the development of a multi-risk methodology from a climate change perspective have been carried out (Gallina et al, 2016). It developed the assessment of multiple natural hazards - floods, storm surges, and droughts affecting a given area for the year, season, and decade timeframe. Several methodologies were used to assess the vulnerability of multiple targets to specific natural hazards by means of vulnerability functions and indicators at the regional and local scale. It recommended that the climate impact assessors should develop cross-sectorial collaborations among different expertise

(for example - modelers, natural scientists, economists) integrating information on climate change scenarios with sectorial climate impact assessment, towards the development of a comprehensive multi-risk assessment process.

When planning for the long term and assessing risks, it is important to integrate how the different trends interact in a comprehensive manner to identify risk scenarios for the future. These trends influence and reinforce each other, and determinate risk levels through interconnected processes that are difficult to separate them in order to get a real sense of future risks, and policies that need to be setup to reduce them.

3.2 Development of Adaptation Strategy

3.2.1 Synergy between adaptation and mitigation

Coordinated and effective adaptation strategies are essentially needed to ensure the long-term sustainability of food production under changing climatic conditions. Adaptation to climate change is, however, inevitably a multidisciplinary problem, as it requires the consideration of agro-climatological, technical and socio-economic issues. Thus adaptation management demands integration of methods from different disciplines (Howden et al. 2007). Uncontrolled autonomous adaptation, defined as responses implemented by individual farmers and communities without the intervention of governments or international agreements, is projected to increase consumption of energy, water and land resources and lead to land degradation (Tubiello and van der Velde 2010; Smith 1997) which would potentially result in increased carbon losses. Thus synergy between adaptation and mitigation is needed as a part of the adaptation strategies. The strategies should include practices, which reinforce climate change mitigation potential.

Adaptation to the changing climate is considered being particularly challenging in the developing countries, as they are highly vulnerable to the climate change due to their warm baseline temperatures, the predominance of agriculture in their economies, the relatively low amount of available capital and high exposure to extreme events (Tubiello and van der Velde 2010). Despite the challenges, several technical response options are already available.

In temperate and tropical regions, the management options are expected to have the potential to counterbalance the climate change impacts in the low-to-moderate warming conditions (1–2 °C), although they are expected to face limits under more severe climate warming (Howden et al. 2007). These methods include a) adapting farm management, b) changing crop varieties and species and c) improving water management practices. The methods are mainly extensions of widely known farming practices and are more specifically introduced (Tubiello and van der Velde 2010).

The impacts of the existing management options also have inter and intra-regional variation and in some countries adaptation options may not be sufficient to offset the negative impacts of climate change (Butt et al. 2005). Benefits of technical adaptation methods vary also with the type of crop and with the changes in temperature and rainfall (IPCC 2007). Predictions of the adaptation potential also include uncertainties related e.g. to pest and disease incidence and ability of farmers to adapt to increasing climate variability and frequency of extreme weather events. The expected future contribution of genetically modified crops is also considered controversial (Tubiello and van der Velde 2010) although some novel findings can help to develop e.g. rice varieties, which can enhance rice production in flood-prone areas (Hattori et al. 2009). Despite the prevailing uncertainties in the impacts of the adaptation methods, the technical adaptation options could also be supported by changes in resource allocations and alternative land-use and livelihood options to increase the adaptation potential of the regions.

3.2.2 Changing policies and adaptation to extreme weather events

Coordinated adaptation measures through changing policies are necessary to ensure the long-term benefits and social equity of the adopted measures. In order to build capacity for better collective understanding as well as to build stronger strategic and technical capability for adaptation, the adaptation policies need to support information communication as well as research and analysis operations (Howden et al. 2007). Training inhabitants to new jobs will be essential where climate change leads to large land-use changes (Howden et al. 2007). To have the capability to support new technical management and land-use arrangements, new infrastructure, funds and institutions are also essential (Tubiello et al. 2009).

New policies may be needed and would also require the capacity to be able to continuously improve adaptation to include targeted monitoring of the costs, benefits and impacts of the adapted policies (Howden et al. 2007). Climate change and socio-economic pressures are expected to increase the demand for food as well as other resources.

Adapting to extreme weather events can be considered more challenging in comparison with the adaptation to the increased mean temperatures, since the extreme events may not have historical analogues. In general, adaptation to extreme events is, however, possible through reducing vulnerability and enhancing resilience of the food production systems. For example, practically capacity building rather than disaster relief would increase the resilience to extreme events (Mirza 2003) and improved flood forecasting and warning practices would reduce the vulnerability of agricultural systems. Recent technical advancements have increased the ability to adapt to extreme climate variation (Cane et al. 1986). Also the early warning systems related to extreme events have improved (Dilley 2000). However, social inequities can also prevent part of the society from benefiting from these adaptation options and thus hinder the adaptive capacity of the society (Pfaff et al. 1999).

3.2.3 Costs and bottlenecks of adaptation

Costs of the coordinated adaptation to climate change and the associated risks in developing countries have been estimated to require annually approximately 100 billion US dollars, which markedly exceeds the projected financial flows in rural development in the coming decades (Tubiello et al. 2009). Potentially a large part of the required financial flow is expected to be generated through carbon markets by boosting activities related to both agriculture and forestry, including methods such as reducing deforestation (Tubiello and van der Velde 2010). Without the carbon markets the funding needs are estimated to fall an order of magnitude short (Tubiello and van der Velde 2010). Currently the clean development mechanism projects are, however, regionally unevenly distributed and only approximately 1% of their financial flow reaches Africa (Tubiello and van der Velde 2010), which suggests that the geographic distribution of the projects need to be widened.

Generally, further increasing the number of these projects include both administrative and technical challenges, including investor risks, inadequate infrastructure and unclear land tenure (FAO 2008). Further, more agricultural activities could be included in the list of clean development funding projects and aggregation of different actors within a region could be one method to further scale up the projects and thus increase the attractiveness of the projects for investors (Tubiello and van der Velde 2010).

4. Challenges for Management of the Extreme Events

4.1 Flood Management

Since the dawn of time (WMO, 2006), civilizations have prospered on flood plains, taking advantage of the benefits of floods, which are much more than just a hazard. Housing is often

located in flood-prone areas, together with economic activities. These zones often represent a major source of income, livelihood and housing for thousands of communities, while floods play a key role in these processes.

Until 1927, the main flood policy of U.S. Army Corps of Engineers was “levees only”. After the great flood of 1927, flood management by the reservoirs was also included. The concept of non-structural measures (NSMs) was first used in the context of flood control some 50 years ago, as a means to reduce the ever increasing damages, without unduly expanding the costly infrastructure. In that sense, NSMs were perceived rather as complementary additions to the essentially structural solutions to flood control, in order to reduce costs and enhance efficiency. This concept has changed in the last few decades with the introduction of new approaches as documented in the following publications:

(a) Development of the new Swiss Safety concept for dams in 1985.

(b) Publication of “Manual on non-structural approaches to flood management” by ICID (ICID, 1999).

(c) Bulletin on ICOLD, “Non-structural risk reduction measures; Benefits and costs for Dams in 2001 (ICOLD, 2001)

(d) Integrated Flood Management Concept Paper, WMO No 1047 in 2003,

(e) Publication of U.S. Army Corps of Engineers manual on “Adaptive Management for Water Resources Project Planning” in 2004.

(f) Publication of the proceeding of Q53 of ICID congress on Harmonic coexistence with floods in Beijing in 2005.

(g) UN Water 2010 recognizes Integrated Flood Management approach as robust and adaptive for adaptation to climate change

In the specific case of floods, a recent paradigm shift, moving from “flood control” to “Integrated Flood Management” (IFM) (WMO, 2006), that is, from the “need to master” floods from a technical standpoint to the “need to manage them” from every point of view – technical but also social, political and economic, by anticipating the event rather than undergoing it. In the 21st century, it is recognized that the approach to flood management has to be increasingly adaptive and a combination of non-structural and structural.

Figure 2. Integrated Flood Management approach

Integrated Flood Management is the approach that promotes an integrated – rather than fragmented – approach to flood management. It integrates land and water resources

development in a river basin, within the context of IWRM, and aims at maximizing the net benefits from the use of floodplains and minimizing loss of life from flooding. Uncertainty and risk management are defining characteristics of choice, and risk management is a necessary component of the development process, essential for achieving sustainable development.

The application of a risk management approach provides measures for preventing a hazard from becoming a disaster. Flood risk management consists of systematic actions in a cycle of preparedness, response and recovery, and should form a part of IWRM. The actions taken depend on the conditions of risk within the social, economic and physical setting, with the major focus on reducing vulnerability. UN System (UN Water, 2010) recommends Integrated Flood Management as a robust and adaptive approach to manage floods. Flood risk assessments, which form an essential element in such approaches, should incorporate climate change effects on the magnitude of floods and the vulnerability of populations.

An important aspect of evolving concepts of engineering practice is the way uncertainty is recognized and addressed. It is today widely appreciated that many consequences of civil engineering investments cannot be precisely forecasted. Whether the objective is to take advantage of new opportunities or to insure against bad outcomes, the goal is to create the capacity to respond appropriately as new situations which may include unforeseen surprises develop. Flexibility over the life of the project is essential to effective development and functioning of civil engineering systems.

Public awareness for and education in flood risk are key elements for flood management in flood prone areas. A high level of awareness for flood-related risks is required to have effective and efficient flood risk reduction measures; e.g. successful evacuations require awareness and planning among the population of what to do and where to go in a flood emergency (WMO, 2009). Flood Maps are tools to visualize flood information for decision makers and the general public. These maps form the basis for developing flood risk scenarios based on land use, various environmental and climate conditions; and form the basis for the planning and implementation of development alternatives (WMO, 2013).

Adaptive management concepts and practices represent innovative, current thinking on resolving conflicting demands and adjusting to changing social preferences and priorities. Many of adaptive management's benefits come in the form of better knowledge of ecosystem response to management actions. This improved knowledge reduces uncertainties and should therefore improve management decisions. Benefits of better future management decisions will be realized in the future. These benefits, however, are difficult to measure and translate into dollars, the standard metric of economic analysis. The intangible nature of these benefits stands in contrast to the direct, up-front costs of adaptive management programs, such as ecosystem monitoring programs, scientific staff, and institutional support. The strategies of Adaptive Flood Management (AFM) are shown in Figure 3. (ICID, 2016)

As an example, in August 2016, a very strong El Niño was forecasted in Iran and subsequently a study was undertaken for six selected basins in Iran, which indicated a good teleconnection of strong ENSO events and associated precipitations in autumn. These forecasts were used for the real time water management during the extreme floods in the south-west basins. In fact, the appropriate authorities issued large floods forecast for the months of November and December (2015) several months in advance. This forecast matched closely with the observed floods and consequently reduced the devastating effects of the floods.

4.2 Drought Management

Drought is a natural but temporary imbalance of water availability, originated from a deficiency of precipitation (e.g., persistent lower-than-average), of uncertain frequency, duration and

severity, of unpredictable or difficult to predict occurrence, resulting in a reduced gap between water supply and demand, and reduced carrying capacity of the ecosystems (Wilhite and Glantz, 1985; Pereira et al., 2009).

Figure 3. The strategies of Adaptive Flood Management (AFM)

Drought is a relative, rather than absolute, condition, and occurs in all climatic regimes, from low to high rainfall areas. Although agriculture is the sector most affected by drought, in both developing and developed countries, other sectors such as energy production, transportation, tourism and recreation, urban water supply, and the environment, are facing significant impacts.

Some drought types are recognized (i.e., meteorological, agricultural, hydrological, and socio economic), depending on the interaction between the natural characteristics of the event and the specific human activities related to the water supplied by precipitation. When meteorological drought (e.g., a lack of precipitation over a region for a period of time) is adopted, precipitation is used for drought analysis (Paulo et al., 2012). Precipitation-based indices have been developed over time in order to quantify a drought as departure of precipitation from the "normal". Widely used indices, such as the Palmer Drought Severity Index (PSDI), the NOAA Drought Index (NDI), and the Standardized Precipitation Index (SPI), use precipitation either singly or in combination with other elements (Shatanawi et al., 2013).

Satellite observations can supply in situ data at high spatial density. Indices, such as the Normalized Difference Vegetation Index (NDVI), the Vegetation Condition Index (VCI), the Temperature Condition Index (TCI), and the Vegetation Health Index (VHI), can be derived (Kogan, 1995). They can profitably be used for monitoring drought events according to vegetation response to environmental stress.

Differently from other natural events, drought is a slow-onset hazard, whose effects accumulate slowly over a rather long period of time. Since duration of drought (i.e., onset and end) is difficult to determine, disagreements between researchers and policy makers can occur with respect to the actual length of a drought event. Drought has both a natural and social dimension, the latter being the factor that moves a hazard into disaster (Whilite et al., 2014). Due to the absence of a unique definition of drought, some confusion can arise on the existence and the degree of severity.

A critical feature of drought is that impacts are non-structural and can spread over areas larger than those hit by other natural hazards, often beyond national borders. This may lead to difficulty both in quantification of the impacts and in disaster relief. In addition, both economies and environment can be affected for long time periods. Natural disasters originate from the interactions between the climate extremes and the vulnerability of human and natural ecosystems to such extremes (WMO, 2013).

Response to drought have been reactive in most part of the world largely adopting crisis management approach. This approach revealed ineffective in most cases, mainly because it does not reduce the risks associated with drought. It is imperative that a more risk-based approach to respond to drought, based on well-established national drought policies and preparedness plans is adopted. Improving the level of preparedness for drought results in a reduction in the societal vulnerability.

Figure 4. The cycle of disaster management (Wilhite, United States National Drought Mitigation Center)

Impacts associated with drought are the results of a wide range of climatic and societal factors. Whether a drought event becomes an emergency or disaster, depends on the vulnerability of people and the environment to such event (IPCC, 2012). In recent years, due to increase in the vulnerability, together with the incidence of drought, the approach to reduction of risks associated with drought is gaining emphasis.

Two main paths can be followed to face drought events: better planning to improve operational capabilities, and mitigation measures to reduce drought impacts. Mitigation of drought effects requires the use of all components of the cycle of disaster management (Figure 4), that is both risk and crisis management.

4.2.1 Post impact interventions

When drought occurs, governments and donors normally follow the steps in the recovery section of the cycle. The return to a pre-disaster state with little attention given to risk management (i.e., preparedness, mitigation, early warning or other prediction actions) can address a short-term need but cannot avoid or reduce future impacts and lessen government and donor interventions. Countries with policies based on crisis management have little reduction in risk when moving from one drought event to another (WMO and GWP, 2014).

These responses to drought are generally reactive both at the national and regional scale (Whilite and Pulwarty, 2005). Treatment of symptoms is often untimely, poorly coordinated, and ineffective to reduce the impacts of droughts, since driven by crisis rather than prevention. Reactive approach is partially due to the uncertainty and unpredictability of drought events, especially in the past. This situation have hindered development of different approaches to drought management, no longer based on reactive practices but on the underlying causes for the vulnerability.

Post-impact interventions, carried out by both developing and developed nations worldwide, are normally in the form of emergency assistance programs to the victims of the drought. This reactive approach does not sustain the reduction of vulnerability, since behaviours or resource management practices are not expected to change. This attitude does not encourage neither self-reliance nor coping capacity.

4.2.2 Pre-impact government programs

Concern that droughts are increasing in frequency, severity and duration due to climate change, together with available technologies to support drought early warning and information delivery systems, stimulates governments throughout the world to switch from responses to drought based on crisis management towards national drought policy based on risk management. Drought policy is developed in advance of drought and maintained between drought events.

Pre-impact programs aim to reduce vulnerability and impacts through a large number of non-structural mitigation measures. Among others, they include seasonal forecasts, water conservation (demand reduction), and increased exploitation of ground waters, water reuse and recycle, construction of reservoirs, interconnection of water supplies between communities, drought planning and education (Wilhite and Rhodes, 1993). Insurance also can be categorized in this policy type.

Where vulnerabilities are identified (population groups, regions, sectors), measures that are able to reduce the risk associated with future drought events can also include adaptation measures (WMO and GWP, 2014). Vulnerability of a region is a function also of the sensitivity of the water management that in turn is characterized by adaptation to changing circumstances. Many adaptations are reactive, but others are planned for the future. Adaptation to altered circumstances allows to respond to some consequence of climate change (i.e., drought events). Adaptation in the water sector to cope with adverse impacts follows two approaches: supply side and demand side. Supply side techniques include building new supply and distribution infrastructure, and more efficient management of existing sources. Demand side techniques aim to reduce the demand for water resources through a wide range of measures, such as public awareness campaigns and statutory requirements for water use efficiency (Parry, 2000).

Some economic and agronomic adaptive options are available in agriculture. Most of agronomic strategies are demand side oriented and can be grouped in short-term adjustments and long-term adaptations. Short-term adjustments are the first defence tools to face the event. They include changes in planting dates and cultivars (i.e., early planting), changes in external inputs (i.e., fertilisers and pesticides), and practice to conserve moisture (i.e., conservation tillage

and irrigation management). Long-term adaptations include major changes to overcome the adversity, such as changes in land allocation, introduction of more resistant crop varieties, substitution of crops, enhancement of irrigation efficiency, and changes in farming system.

4.2.3 Preparation of national drought policies and planning techniques

Drought events differ with respect to their physical characteristics between climatic conditions, resulting in local impacts defined by unique characteristics. Preparation of national drought policies and planning techniques should define the key components of the policy, its objectives and the steps in the implementation process. This type of policy response include organizational frameworks and operational arrangements developed in advance of drought and maintained between subsequent drought events. The goal of this approach is to create institutional capacity to improve coordination and collaboration within and between different levels of government and with stakeholders. A national drought policy has specific objectives, different from nation to nation. However, in principle these objectives intend to encourage vulnerable elements (i.e., economic sectors, population groups) to adopt measures promoting risk management, to promote sustainable use of agricultural and natural resources, to facilitate early recovery from drought according to actions consistent with the national policy objectives (Whilite et al., 2014).

4.3 Integrated Water Resources Management

Increasingly competing demands for finite water resources and impacts of climate variability require a more holistic approach to resource management. The Asian Water Development Outlook 2013 (Asian Development Bank) estimates up to 75% of the Asia-Pacific region being water insecure. Combined with increasing demands, water can no longer be looked at from a single lens. The impacts of one user on another and associate trade-offs need to be considered.

According to the definition of the Global Water Partnership, “Integrated Water Resources Management (IWRM) is a process which promotes the coordinated development and management of water, land and related resources in order to maximize economic and social welfare in an equitable manner without compromising the sustainability of vital ecosystems.” It is pertinent to note that IWRM is a process and not an end in itself.

IWRM strategies are based on the Dublin Principles which were presented at the World Summit in Rio de Janeiro in 1992. These include recognition of water as finite resource with multiple uses; (ii) requiring more holistic management based on supply and demand considerations; (iii) social and economic value of water; (iv) recognition of stakeholder participation in decision making and (v); women’s role in water management.

Over the past decade much progress has been made with increasing awareness on the concept of IWRM in the Asia Pacific region and subsequently, embedding in the water policy framework of an increasing number of developing and middle income countries. For example, in India the main objective of the National Water Mission is “conservation of water, minimizing wastage and ensuring its more equitable distribution both across and within States through integrated water resources development and management.” In the People’s Republic of China, the 2002 Water Law reinforces the need to strengthen the responsibilities of river basin commissions and local water bureaus in respect to integrated water resources planning. Multilateral development banks like the Asian Development Bank have also endeavoured to embed IWRM through strategic and operational plans and support to regional knowledge partners like the Network for Asian River Basin Organizations.

Adaptation to climate change is closely linked to water and its role in sustainable development. To recognize this reality and to respond accordingly presents development opportunities, various necessary adaptation measures that deal with climate variability and build upon

existing good land and water management practices have the potential to create resilience to climate change and to enhance water security and thus directly contribute to sustainable development. Creating the infrastructure for water resources development and distribution has shown high human and macroeconomic benefits; conversely, countries lacking this capability have suffered damaging shocks from droughts and floods. More water storage is required to manage increased variability of water resources (UN-Water 2010)

A good example is the ADB financed loan, the Karnataka Integrated and Sustainable Water Resources Management Investment Program, India. The state of Karnataka is water-stressed, with increasing water demands from urban and industrial sectors. This is exacerbated by uneven spatial and temporal distribution of water resources and the predicted impacts of climate change. Overall, the investment program area is found to be vulnerable to increased incidence of seasonal droughts. This increases the need for a well-planned and methodical approach to water resources management. An integrated approach to water resources management is a means to reconcile varied and changing water uses and demands since it provides greater flexibility and adaptive capacity than conventional water resources management approaches.

Adaptation to climate change to reduce vulnerability in the water sector should involve far more than just water managers. Increasing social vulnerability to water stress (in terms of drought and flood) in many parts of the world reflects a wide range of pressures, many of which are outside the responsibility of water managers. Reducing vulnerability to climate change-induced flood and drought will require decisions about issues such as development and planning control, fiscal incentives (such as subsidized insurance or government disaster relief) to occupy (and continue to occupy after loss) hazard-prone land, and wealth enhancement.

The fourth edition of the World Water Development Report (WWAP, 2012), 'Managing Water under Uncertainty and Risk' seeks to demonstrate, among other messages, that water underpins all aspects of development, and that a coordinated approach to managing and allocating water is critical. It highlights that more responsible action by all water users has enormous potential to lead to better outcomes - but requires political, social, economic and technical responses at all levels of government, businesses and communities, from local to international.

Over the past decades the translation of IWRM into water policy, planning and institutional development has also had the knock on effect of a more prescriptive rather than location or basin/sub basin specific approach. The latter would be based on understanding the goals or targets for basin/sub basin water resources for example, improving agriculture water productivity and defining a prioritized set of actions to achieve. In certain cases, activities like performance benchmarking of a river basin organization may be regarded as a priority action – using a blueprint rather than tailored approach.

Rethinking IWRM in the context of water security and climate change adaptation may be a way to move forward. The Asian Water Development Outlook (AWDO) has five key dimensions of water security which would be affected by population dynamics and impacts of climate change.

As an adaptation action it would be useful to consider gradual improvements on the IWRM spiral as a reflection of enhanced water security. This would require planners and decision makers to consider the following:

1. Risks to the basin or sub basin (including climate change impacts on hydrology).
2. Critical users within the basin (e.g. if domestic users then assess their water security status – under key dimension 1 based on relevant indicators like access to piped water supply and sanitation).

3. Assess the basin or sub basin targets or vision for the future – e.g. is there a net shift in allocations required between agriculture and domestic use, have water quality targets been set for improved domestic supply and river health and are there environmental base flow requirements.
4. Consider the risk of climate change impacts to ascertain the trade-offs required.
5. Based on the assessment consider the priority actions to increase water security in the sub basin and to respond to adaptation requirements. E.g. installation of river flow measurements, use of remote sensing to establish agriculture water productivity, strengthening institutional capacity for climate proofed domestic water supply design, monitor water quality, stakeholder awareness raising and establishing performance targets for the basin etc.
6. Develop a road map with indicators, roles of agencies and timelines.
7. Review performance and achievements, and constraints and update road map with continuous monitoring.

We are increasingly witnessing increasing frequency and magnitude of extreme events and regional climate variability in the Asia region. This not only introduces an element of disaster risk management into the overall equation of improved and integrated water resources management, but further reinforces the need for tailor made adaptive solutions.

The past decade has demonstrated that moving from a concept of IWRM to applying the process in an operational context requires further contextualization. An example is the initiative for Improved Management of Extreme Events through Ecosystem-based Adaption in Watersheds (ECOSWat). The program is commissioned by the German Federal Ministry for Environment, Nuclear safety and Buildings (BMUB) and supported by the Government of Thailand. It provides a more locally based approach with local water agencies (in pilot river basins) to plan and assess ecosystem-based adaptation measures for protection against the effects of extreme events. Lessons learned from the project have been fed into national-level adaptation strategies for the water sector.

Much of the base work has been accomplished in increasing regional understanding of a more integrated approach to water management. There is also an increasing awareness of the risks and impacts of climate variability and extreme events. What is more challenging is taking the lead in drilling down further into tailored solutions and approaches and highlighting their benefits to all stakeholders.

5. Conclusions

This paper, overviews the background and structure of the issues about management of climatic extremes with special focus on floods and droughts, aiming at facilitating the discussion on this topic as the sub-theme 2 for the Second World Irrigation Forum.

To reduce the disaster risk, the global and local society or community need to assess the weather and climate events with their magnitudes, frequencies, variabilities as well as the forces, the vulnerability of the region and society, and the exposure for the events. The climate change, however, is not easy to prediction and carries high level uncertainty.

Under the current uncertainties in climate change impact projections, improving resilience of the local systems is one approach to reinforce the capability of societies to better cope with the extreme events. In this situation, one of the essential and significant attitude is the adaptive approach. Since the factors associated with climate change and its apparent impacts are difficult to be projected and evaluated at the present level of scientific understanding it would be more effective and feasible to manage the extreme flood and drought through integrated

and adaptive approaches. Particularly the coordinated adaptation measured are needed since autonomous adaptation might lead to the increase of emissions and degradation of ecosystems, which could further reinforce the negative impacts of the climate change.

The concept and approach of adaptive management is found in many sections of this paper. Here, main points of the sections are summarized as follows:

The extreme events will affect natural resources such as soil fertility and available water resulting in increased vulnerability of agricultural production as the negative impacts, with serious water stress, land degradation and desertification as well as water logging and land inundation. The extreme flood and drought with changing temperature affect the hydrological condition of a basin and farmland, and will make it increasingly difficult to plan for cultivation activities such as each process in the cultivation and water management practices.

When planning for the long term and assessing climate change risks, it is important to integrate how the different trends interact in a comprehensive manner to identify risk scenarios for the future. These trends influence and reinforce each other, and determinate risk levels through interconnected processes that are difficult to separate them in order to get a real sense of future risks, and policies that need to be setup to reduce them. Coordinated and effective adaptation strategies are essentially needed to ensure the long-term food and water security under changing climatic conditions.

Adaptation to climate change is inevitably a multidisciplinary problem, and it requires the consideration of agro-climatological, technical and socio-economic issues. The adaptation management demands integration of methods and synergy with mitigation of climate change. Innovative, coordinated and effective adaptation strategies require the capacity to adaptation to be continuously improved and targeted monitoring of the costs, benefits and impacts of the adapted policies.

Many of adaptive management's benefits come in the form of better knowledge of ecosystem response to management actions. This improved knowledge reduces uncertainties and should therefore improve management decisions. These benefits are difficult to measure and translate into the standard metric of economic analysis. The intangible nature of these benefits stands in contrast to the direct, up-front costs of adaptive management programs, such as ecosystem monitoring programs, scientific staff, and institutional support.

Response to drought, which has been reactive in most part of the world have proved to be ineffective in most cases. Whether droughts characteristics will change or not, it is imperative a more risk-based approach to respond to drought, and based on developed national drought policies; preparedness plans and widely disseminated drought early warning systems.

Floods need to be recognized as natural phenomenon that have multi-faceted ecological benefits but do turn into disasters if the vulnerable sections of the society are exposed, particularly in the extreme events. Integrated Flood Management approach that draws maximum benefits of flood plains within the framework of Water Resources Management, Land use planning and Risk Management principles need to be adopted.

Adaptation to climate change to reduce vulnerability in the water sector should involve far more than just water managers. Mechanisms for interaction among various stakeholders, coordination among various agencies and collaboration among various disciplines for establishing better management systems needs to be promoted, not only against the climate change but also for everlasting improvement of the systems.

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Sub-Theme 3
Key and Smart Actions to Alleviate Hunger and Poverty through Irrigation and Drainage

ABSTRACT

In the pursuit of information to support the policies and actions to alleviate hunger and poverty from a perspective of the role and impacts of irrigation and drainage, this paper attempts to provide correlation between water scarcity, community and poverty. Many reviews have found strong direct and indirect relationships between irrigation and poverty. One of the main goals of the international community is to eliminate hunger and poverty and in this perspective, through the Millennium Development Goals much progress has been achieved and evidence obtained. Sustainable Development Goals and various United Nations and other initiatives, intend to move forward this agenda by making it a part of the broader development frameworks. In this paper, the important elements of the irrigation and drainage that affect the alleviation of hunger and poverty have been discussed. These elements are grouped into governance, rights-based developments, water rights and pricing, management, efficiency improvement, and role of technology. Both the potential and the need to make use of innovative technology and solutions in irrigation are underlined and these can be used to cater the challenges in different sub-sectors. The main focus of these solutions are on maximizing productivity and efficiency, reducing water losses, achieving sustainable intensification and managing demands on water resources and the associated trade-offs.

1. Introduction

Agriculture is expected to feed an estimated population of more than 9 billion by the year 2050 through 60 % increase over the 2006 food production levels, with 80% of the increase stemming from intensification which is essentially possible under irrigation. At the same time, increasing water scarcity and demand for water resources from other sectors is putting unprecedented pressure on agriculture that uses approximately 70% of the total water withdrawal worldwide to release part of this water.

Internationally, food security has slowly, but markedly, improved during the past years. Approximately 842 million people today are estimated to be experiencing chronic hunger. The 2013 Global Food Security Index (Figure 1) provides a worldwide perspective on which countries are the most and least vulnerable to food insecurity.

Irrigated agriculture has been recognized as one of the important components of the world food security and specifically in reduction of rural poverty. Irrigated agriculture uses some 20% of the total farmland in the world but produces 40% of the food.

Approximately 75 percent of poor people in developing countries live in rural areas. In these areas, agriculture is the main source of income. Access to adequate food in the rural areas of many developing countries depends heavily on access to natural resources, including water, that are necessary to produce food. About 17 percent of global agricultural land is irrigated and contributes about 40 percent of the global production of cereal crops (Bhattarai et al., 2002).

One of the sub-theme of 2nd World Irrigation Forum ‘Key and smart actions to alleviate hunger and poverty through irrigation and drainage’ focuses on the smart actions and use of innovative technology to provide the catalyst for the broader aspects of agricultural development especially in LDCs to alleviate poverty and hunger. The key is to adopt ‘right’ actions and

technology which enable users to innovate and adapt them in to their circumstances. This background paper is intended to provide the basis for further discussion on these topics under three broad categories:

- Water and climate smart approaches for sustainable smallholder agriculture
- Financing mechanisms for development and management of irrigation and drainage projects
- Adaptation measures for rural water management for water and food security

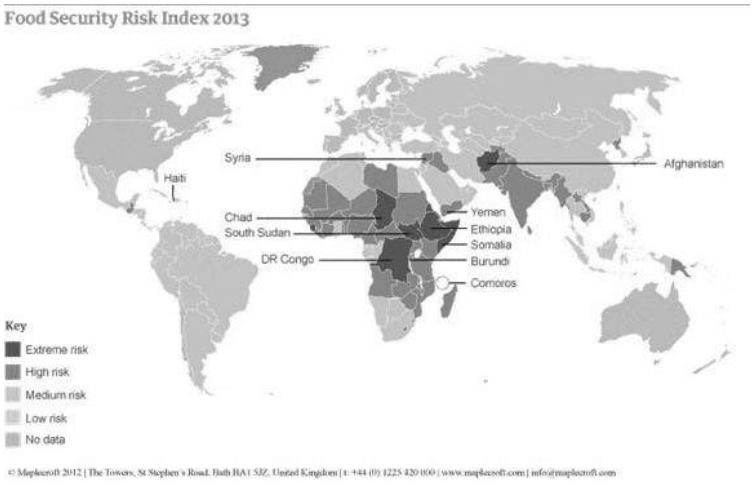

Figure 1. Food security index 2013 (The Economist Intelligence Unit Limited)

2. Irrigation and poverty and hunger linkages

Many reviews have found strong direct and indirect relationships between irrigation and poverty (Hussain and Hanjra, 2004). The benefits of irrigation can be attributed to higher production, higher yields, less reliance on weather condition, lower risk, and increase in farming activity year-round. Landless farmers may benefit less in short-term but enhancing productivity, increasing cultivated areas and providing adequate access to water creates more job opportunities for landless farmers, as well. Irrigated agriculture significantly contributes towards generating rural employment and maintaining rural livelihoods (Bhattarai et al., 2002).

The role of irrigation in the alleviation of poverty has been the focus of many international communities and groups in the recent years. It is clear that more investment is going into the modernization of the existing systems to improve the efficiency of water use and increase the crop production. This approach can directly benefit farmers and alleviate poverty. It can also enhance the livelihoods of those who are not the primary beneficiaries (ICID 2014). There is the employment possibilities for the landless poor on larger farm units and in distributive trades, as well as product-processing.

Improved irrigation access significantly contributes to rural poverty reduction through employment and livelihoods within a region. Indirect benefits, such as more stable rural employment as well as higher rural wage rates, help landless farm laborers obtain a significant share of the improved agricultural production (Chambers 1988; Barker et al., 2000). Lower food grain prices benefit poor urban and rural landless communities more by enabling them to

purchase required food items at affordable prices. Keeping food prices at relatively low levels also greatly assists the industrial sector to avoid the pressure of increasing the real wage rate. In this process, improved agriculture indirectly 'subsidizes' the industrial sector of the economy as well (ICID 2014).

Irrigation enables smallholders to adopt more diversified cropping patterns, and to switch from low-value subsistence production to high-value market-oriented production. Increased production helps make food available and affordable for the poor. Climate change and variability links directly and indirectly to irrigation, though, for example, changes in rainfall patterns, increased scarcity, impacts on land and soil, and increased competition. Irrigation also provides a defense against droughts, which are predicted to occur more frequently. Irrigation played a vital role in green revolution, occurred in twentieth century, that helped saved over a billion people from starvation in many countries, particularly in Asia and South America. However, since then irrigation has been blamed for being highly inefficient and for causing damage to environment and ecosystems. Lack of drainage in many countries is causing water logging and salinity and destroying otherwise fertile lands.

Irrigation development, it has been argued, has displaced marginal and poor farmers and have made them landless laborers driving them to become urban dwellers in certain regions (Chambers 1988). However, the positive social and economic impacts of irrigation far outweigh some of these negative impacts and can be compensated through improved planning, implementation and management of irrigation systems (Bhattarai et al., 2002), and broader safety nets for the urban poor.

As population growth and demand for water use in irrigation rapidly increases, struggle for a secure water supply will become more difficult to administer, especially in arid parts of the world. Large arid areas with absolute water scarcity which affects millions of people, many of whom are poor and underprivileged. It can be stated that there is a strong linkage between irrigation and drainage, and hunger and poverty alleviation, in which the poor benefits from well managed irrigation through higher yield, lower risk of crop failure, adoption of diversified cropping patterns, increased high-value and market-oriented crop production, and fixed employment (Hussain and Hanjra, 2004).

Deliberations in the International Commission on Irrigation and Drainage (ICID) Task Force on the "Role of Irrigation in Poverty Alleviation and Livelihoods" can be summarized as:

- Irrigation professionals need to be more sympathetic to the actions of the poor in making better use of irrigation systems to improve their circumstances (e.g. multiple use of canal banks for farm to market access).
- Many of the poorest members of the community are not able to be farmers, or find their best opportunities in irrigated farming, or in agriculture at all.
- Of those that remain in agriculture, most depend on rainfed cropping or become pastoralists, or may find other employment in towns.
- Most irrigation schemes have multiple use and these additional uses can provide opportunities for the poor, which may be non-agricultural but depend on irrigation development for water.
- The role of irrigation in poverty alleviation may be small in terms of simply providing water to grow crops, but may be significant in enabling other uses of the infrastructure as well as adding to food security.

3. Historical Development

From the 1970 to the 1990, the government sector, with significant intervention by the international development banks, financed large irrigation projects having strong positive effects on economic growth, benefiting the poor. In the late 80s, it became difficult to justify new irrigation development costs due to declining crop prices and increasing of development costs for new irrigation schemes. While on one hand, financial capability has been lacking for new infrastructure as well as for modernizing and rehabilitating present structures, on the other hand, there has been an increase in the private sector financing of large water-sector infrastructure, and small-scale irrigation system with particular interest on groundwater development because of the private level of control it offers. Recently, in order to augment the performance of the irrigation sector, the possibility of involving the private sector through Public–Private–Partnerships (PPPs) has been explored and adopted with the financial support of development banks (i.e. World Bank and Asian Development Bank).

Despite the significant achievements in irrigated agriculture, water use for irrigation is still generally inefficient. On average, half of the water diverted or stored for irrigation evaporates and percolates into the ground without watering crops. Likewise, consumption for irrigation has lower economic value of water compared to industrial, municipal and domestic consumption. Wherein, there will be a natural tendency to reduce water allocation to agriculture in favour of other uses.

It is imperative to have drastic improvements in irrigation to have a significant impact on poverty alleviation and ensure water allocation for agriculture while sustaining natural resources. Irrigation professionals have an important role in this path. They need to sufficiently recognize the multiple use of water. Developing advance methods and smart irrigation systems can reduce significantly the water consumption and increases the water efficiency. In recent years, the cost of technology has been reduced and it is now a practical approach to use those technology in farm management.

Generally, water shortage leads to several form of cooperative association, especially in isolated farmworker societies. Since individual farmer could not manage to pay all needed equipment to divert or draw water, the community developed centralized irrigation system with specific rules for water distribution. Depending on the farmers' wealth and social status, certain volume of water is allowed to flow on his land. Irrigation has come a long way, from its foundation to the present situation where there is rightful water distribution to all stakeholders. This should continue, and all improvements in irrigation should be geared towards equitable water distribution and poverty alleviation.

4. State of the Art

Water is an integral element to human food security. Water of sufficient quantity and quality is also essential for agricultural production but it is increasingly under stress (HLPE 2015). Traditional surface irrigation practices have in the past been suitable for smallholders who are fortunate enough to have abundant low-cost supplies of water. However, the traditional practices smallholders use do not utilize water very efficiently in terms of crop yield per unit of the water applied (Ayele and Tedla, 2006). Since water is usually the most critical factor that directly affects the crop production, it is critical that smallholders begin using more efficient water supply and irrigation technologies.

Finding right technology is the main challenge and providing appropriate and efficient irrigation system is not an easy task. It usually requires the development of low-cost and easy to operate systems. According to Amadei (2004), an appropriate technology is usually characterized as small scale, energy efficient, environmentally sound, labor-intensive, and controlled by the

local community. In addition to technology, reform in policies and water governance is also required to facilitate the access of poor communities to the irrigation water. Right to water does not justify the subsidized water for irrigation and proper use of water can increase the farmers' income and, in turn, they can pay for the services that they use.

Adapting agriculture to climate change in all fronts is essential for securing adequate and nutritious food for all. It is also a driver for and is impacted by technological change and innovation in a broader spectrum. This includes interventions for deforestation, land degradation and desertification, which result from overuse of natural resources and are exacerbated by climate change, creating, in return, negative impacts on the quantity and quality of reliably available water resources. Measures taken to cope with water scarcity will help alleviate the direct and long-term effects of desertification on land and soil quality, soil structure, organic matter and soil moisture, which collectively contribute to climate change adaptation and mitigation.

Climate-smart agriculture (CSA), as defined and presented by FAO at the Hague Conference on Agriculture, Food Security and Climate Change in 2010, addresses food security and climate challenges through three main pillars (FAO 2013):

i. sustainably increasing agricultural productivity and incomes;
ii. adapting and building resilience to climate change; and
iii. reducing and/or removing greenhouse gases emissions, where possible.

4.1 Water Governance: A rights-based approach to water for food security

A recent report (HLPE 2015) on food security and nutrition (FSN) describes the multiple interfaces between water and food security and nutrition (Figure 2).

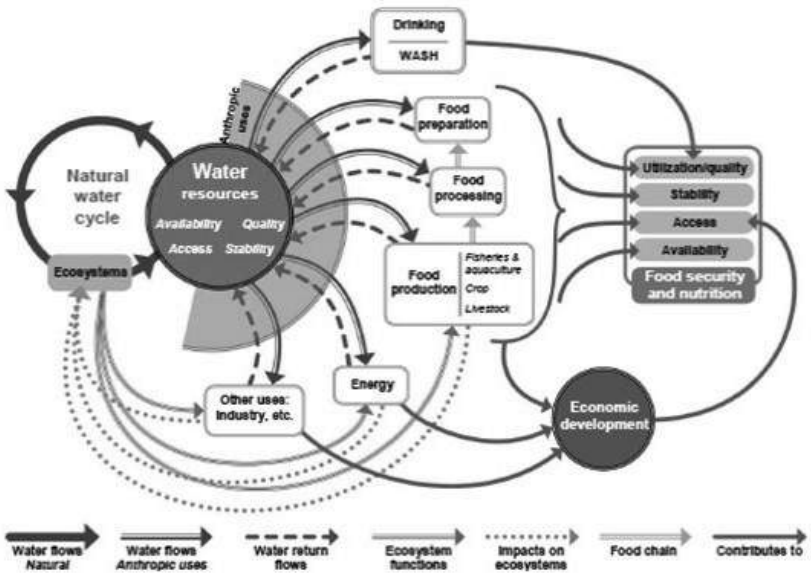

Figure 2. The multiple interfaces between water and food security and nutrition (HLPE 2015)

It considers four dimensions of water - availability; stability; water quality; and access. These dimensions are similar to the four dimensions of food security and are in line with the Sustainable Development Goals (SDGs), in particular, SDG 2: "End hunger, achieve food security and improved nutrition and promote sustainable agriculture" and SDG 6: "Ensure availability and sustainable management of water and sanitation for all".

There have been both express and implied references to a right to water in public international law. Although human rights to food and clean water have been recognized by most countries, in reality the access to these two basic rights have been elusive for millions of poor people in the least developed countries. Inequity in access to food and to water is evident in majority of the least developed and developing countries, in particular the ones that also suffer from water scarcity.

HLPE has recognized that the limitations of the widely-used concept of integrated water resources management (IWRM) in addressing conflicts, suggesting that IWRM, while providing a comprehensive framework that can bring together economic, social and environmental objectives, is not well-equipped to tackle implementation challenges at the ground level. Instead, they recommend: sustainable ecosystem management and conservation to ensure continued availability, quality and stability of water for FSN; improving the resilience, water efficiency and water productivity of existing agricultural systems; and improving the governance of water for FSN, including promotion of a rights-based approach.

They refer to relevant guidelines and principles, such as the right to adequate food, the right to safe drinking water and sanitation, the Voluntary Guidelines for Security Sustainable Small-Scale Fisheries in the Context of Food Security and Poverty Eradication (VGSSF), and the Voluntary Guidelines on the Responsible Governance of Tenure of Land, Fisheries and Forests (VGGT), to provide a basis for further action to safeguard water for FSN. Various tools for managing water scarcity and allocation are discussed, including water use authorization, tradable water permits systems, and water pricing (HLPE 2015).

Institutions providing water services and the ones with mandate to protect people's right to food and to water – not only for health and hygiene but for agricultural production as well - are failing and need to be inclusive instead of servicing only to the influential and powerful few. People get access to water not only through formal water rights and institutions but informal arrangements also determine who gets access to water (FAO 2016). In the context of increasingly formalized water rights, water tenure of vulnerable segment of the population – men and women - has to be strengthened and protected for them to have access to water for food production and for health, hygiene, and sanitation.

Contrasting policies and competing uses of water from different sectors, coupled with increasing impacts of climate change and variability, exacerbate water access issues and have negative impact on efficiencies of resource use, particularly in water scarce situations. It is extremely important to ensure coherence in policies on water, agriculture, and food security in order to address issues impacting smallholders' access to water for agriculture production.

Allocation of water resources is one of the most important components of the governance, especially in water scarce situations. Different countries have different systems, rules and priorities for allocating water to different sectors and different uses at various scales – river basin, national, local. Ensuring water allocation for food production and for fulfilling basic needs of poor and marginalized population is a big challenge, particularly when it is fairly difficult to assess the value of such allocations in monetary or economic terms. Water allocation in river-basins that are shared by different countries or different administrative units is particularly

challenging. The first step in good governance and water allocation is to carry out water accounting and understand not only the surface water fluxes but also interconnectedness of surface and ground water.

Considering multiple interfaces that water has with food security and numerous stakeholders and actors involved with competing interests and uses, good governance of water resources is required for achieving SDG 6 and SDG 2. In particular, enhanced Governance of Irrigation and drainage sector can go long way in helping countries at national and local levels in achieving food security through providing the poor and vulnerable men, women and children with equitable access to water for health and for 'wealth' – income generation.

4.2 Managing Irrigation and Drainage Systems

Irrigation can help achieve food security however, expansion of irrigated agriculture and water development are possible in some countries especially in Africa. In most of the other contexts modernization of irrigation systems is the only way forward to achieve improved water productivity and therefore food security.

According to AQUASTAT – the largest online database of FAO on water – in 2012 over 324 million hectares were equipped for irrigation worldwide, of which about 85 percent or 275 million ha are actually irrigated. Many countries in Asia, North Africa, Near East, Western Europe, North and South America irrigated area is up to 50% or more of the total cultivated area (Figure 3). This means that potential for expansion of the irrigated areas in these countries and regions is very limited.

However, Sub-Saharan Africa is the region with the lowest percentage of the cultivated area that is irrigated, just over 3 percent against almost 21 percent at global level. At the same time it has the highest prevalence of undernourishment (FAO 2016).

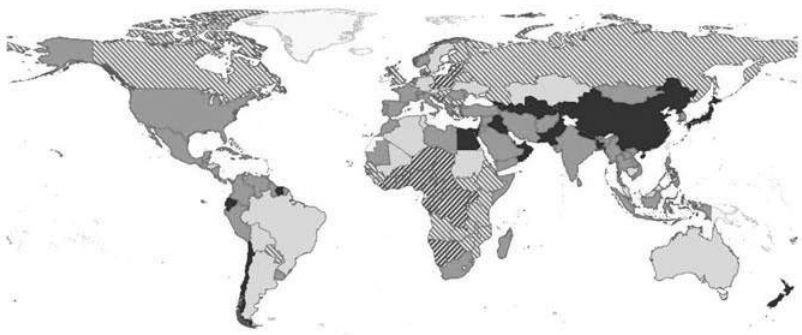

Figure 3. Area equipped with irrigation as percentage of cultivated area (2012) (FAO 2016)

In Africa there is a potential of 43 million hectares that can be irrigated but only 13 million hectares are presently under irrigation. Figure 4 shows the trends in the share of total cultivated area that was equipped with irrigation facilities in the SADC countries between 1990 and 2009 (FAO 2016). It was found that throughout the SADC region, only 8% of the cultivated area was equipped with irrigation facilities. SADC member states need to take serious measures to increase investment in irrigation projects, in order to tap the potential of irrigation to increase agricultural productivity and food security, and reduce poverty.

Groundwater as a source of irrigation water accounts for about 40% - 112 Mha out of total 275 Mha - of the total irrigation in the world (GWP 2012). In South Asia it accounts for more than 50% of the total irrigated area (Table 1). In many countries, groundwater extraction has provided farmers, large and smallholders, with the opportunity to grow crops and use the water for other livelihood purposes – thanks to availability of low-cost water lifting technology. However, in many cases groundwater is not a renewable resource and is depleting fast. Efforts need to be made to monitor groundwater use and changes in aquifers in order to sustainably use the resource.

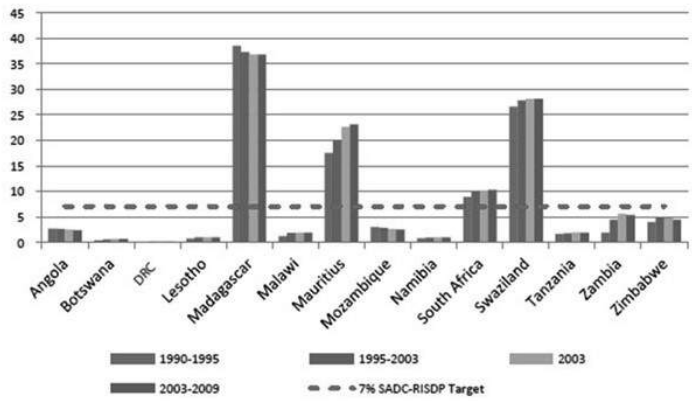

Figure 4. Percentage of cropland area equipped for irrigation in SADC countries (1990-2009). (FAO 2016)

Table 1. Global survey of groundwater irrigation (GWP 2012)

	Groundwater Irrigation		Groundwater Volume used	
	Mha	Proportional total (%)	Km^3	Proportional total (%)
South Asia	48.3	57	262	57%
East Asia	19.3	29	57	34%
South-East Asia	1.0	5	3	6%
Middle East and North Africa	12.9	43	87	44%
Latin America	2.5	18	8	19%
Sub-Saharan Africa	0.4	6	2	7%
Global Total	**112.9**	**38%**	**545**	**43%**

Efficiency of irrigation schemes, predominantly surface irrigation schemes and systems, is rather low. Far too many irrigation schemes, in particular large scale irrigation systems are performing below their potential - their productivity levels and efficiencies are low and water delivery services to farmers and other water users are often neither reliable nor flexible. According to some FAO estimates, average overall efficiency of irrigation schemes is 56%. Figure 5 shows a high potential for increase in efficiency in many parts of the world. Central Asia, Middle East and Southern and Eastern Asia are particularly important as most parts of these regions also suffer with water scarcity.

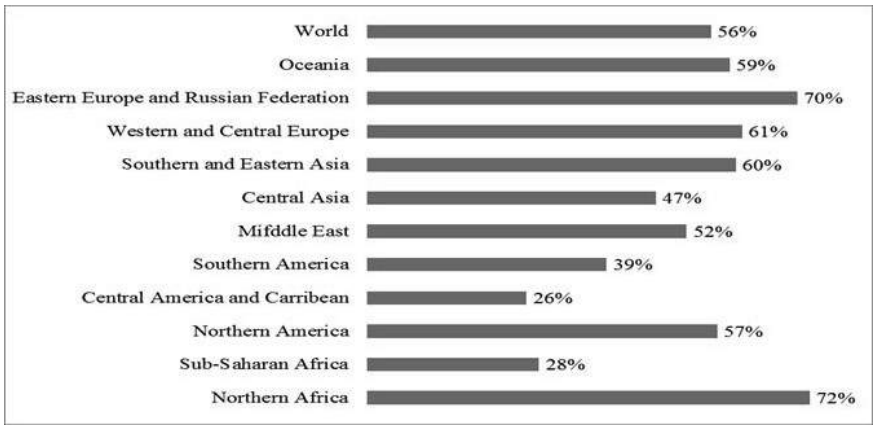

Figure 5. Irrigation Scheme Efficiencies (FAO AQUASTAT, 2016)

Irrigated agriculture needs to perform better and with higher productivity and efficiency in order to feed the world and provide good livelihood to the farmers. This situation requires that the irrigated agriculture sector moves away from the 'business-as-usual' approach and adopts innovative, forward-looking and effective governance to do more with less water. It is even more important if the goal is to achieve a sustainable water and food secure future. This is also acknowledged in the white paper on "Towards a water and food secure future: Critical Perspectives for Policy-makers" produced by FAO and World Water Council for the high level panel discussion at the 7th World Water Forum (2015).

Technological and technical solutions to improve efficiency and productivity of irrigation water are available, for example shifting, where appropriate, from low efficiency surface irrigation to high efficiency pressurized irrigation; lining of canals using appropriate technology, etc. These technologies and techniques are site and condition specific; and may not work if not accompanied by good operation and management. For these to be successful much needs to be done on soft side – for example capacity development of not only farmers but whole chain of actors from decision makers to service providers, to farmers.

5. Future outlook

Poverty alleviation needs more attention and the needs are rapidly changing, and irrigation is only one lever to deal with it. In most cases, irrigation is not the most important means to deal with poverty, although some might believe so. To achieve a true and working irrigation and drainage as a catalyst in poverty alleviation, the international community should be guided by the following objectives:

- Increase the productivity of agriculture through effective and well managed irrigation and drainage systems to meet the demands of a rapidly growing population with a finite land and water resources.
- For individual countries to prioritize agricultural self-sufficiency first before being part of the international market economy.
- Revisit existing design of drainage, dams and pertinent structures to be climate change resilient and at the same time environmentally sound.
- Continue extensive research for innovative technology and solutions in irrigation.

In order to achieve a global food and nutritional security, commitments and investments are needed (UNDESA, 2014) to:

- Produce more nutritious food with less water: Innovative technologies are required to ensure a greener and more sustainable food production. They are needed to improve crop yields; implement efficient irrigation strategies; reuse of drainage water and use of water resources of marginal quality; produce smarter ways to use fertilizer and water; improve crop protection; reduce post-harvest losses; and create more sustainable livestock and marine production.
- Focus on human capacities and institutional framework: Agricultural development in the least developing countries (LDCs) lies mainly in the hands of smallholders, a large majority of whom are women. Therefore, new institutional arrangements are needed that centralize the responsibility for water regulation, yet decentralize water management responsibility and increase user ownership and participation.
- Improve the value chain: From production, post-harvest handling, processing, retailing, consumption to distribution and trade, efficient water and food recycling strategies can be addressed. It can help secure environmental water requirements when reuse of treated water is not culturally acceptable for other uses.

5.1 Investing in Irrigation and Drainage

Investment on irrigation has sharply dropped since the eighties. It is critical to understand the reasons behind that trend and react accordingly. It is crucial to show that the inefficiencies in irrigation management are - most of the time fixable; and less severe than a limited rapid look may show when all aspects of the agriculture chain and when multiples uses of water are considered.

Table 2: Investing in irrigation and drainage – Challenges and constraints

Sector	Challenges and constraints
Water rights	Without well-defined rights to water, infrastructure repair suffers all the well-known problems of a common property resource, with little incentive for anyone to contribute their share of the financing (Herrera et al., 2006). A major challenge in formalizing water rights is to include traditional (often small) systems and to avoid disenfranchising established small-scale water users (Bruns and Meinzen-Dick, 2000).
Water management	The resulting risks for the environment and for society will require careful management. Growing water scarcity will have to be managed as well, with a strong need to further improve water productivity and strengthen the use of demand management approaches. In many river basins, intersectoral competition for water resources is a critical challenge that will need to be addressed.
Infrastructure subsidies	While the subsidies might have positive impact in promoting new technologies and modernizing the infrastructures, on the other hand, it might have negative impacts on water consumption. A study conducted by Brinegar & Ward (2009) have demonstrated that subsidizing modern irrigation infrastructure, even when intended to promote water conservation can increase consumption and reduce supplies available for use outside agriculture. In this case, shifting to drip irrigation induced the famers to select crops with higher ET and yield, increasing the total water need of the irrigated area.

Maintenance Costs	Governments rarely assign high priority to using taxpayer resources to maintain irrigation, infrastructure already built. A common belief held by governments is that even if it subsidizes the development of irrigation initially, they are less willing to assign adequate budgets to keep infrastructure in top form. Another belief is that farmers should pay for maintenance. Nevertheless, it has proved impossible to recover operating and maintenance costs from farmers, with the result that services have been underfunded and have deteriorated, and improvements in productivity and farmers' incomes have been below target. If systems are to deliver quality service, they have to be profitable enough for farmers to earn an adequate surplus, and arrangements for financing operation and maintenance costs have to be clear from the outset. The optimal arrangement is a farmer-managed scheme with full financial autonomy. If subsidies are required, they need to be transparent and reliable (WB 2005).
Water charges	The water charges are fundamental to recover the capital costs, maintenance costs and make the project viable. However, it is very challenging to establish a fair and effective rate especially in poor areas, for several reasons such as: (i) Water pricing must be based on measured deliveries. However, it is widely recognized that the applicability of volumetric water pricing to individual farms is limited to a small subset of technologically and managerially advanced irrigation schemes involving huge investments that cannot be afforded in poor areas and countries (IWMI, 2007). (ii) low water charges can have great benefit on farmer incomes but they can also negatively effect on water saving because it increases the consumption and discourages the farmer to use water saving crops. Low charges are not sufficient to recover the maintenance and operation costs. On the other hand, high water charges might encourage water saving and costs recovery but they might not be feasible for the farmers causing social and economic problems.
Water allocation	In the interim, consultative and participatory arrangements for water allocation will be required. Consultation is a key process in water allocation—along with data collection, analysis, and promulgation, and negotiation—to find optimal sharing of benefits. The challenge over the next 20 years is to develop cost-effective arrangements for doing this and erect a functional framework of facilitating laws, treaties, and regulations. Since the water allocation process is inherently political, effective representation is crucial. A major challenge for the coming decades is to develop strong and effective representative voices on behalf of those stakeholders now underrepresented, including small-scale farmers, women, and the environment (WB 2005).
Regulations	Governments can play a constructive role in influencing water allocations and affecting economic efficiency by establishing regulations, standards or requirements for upkeep in irrigation infrastructure. For an existing regulation to be economically efficient and to achieve community support, the economic benefits of the regulation need to outweigh its costs, and the costs and benefits need to be shared fairly (Ward 2010).
Data	In order to offer attractive investments for the private and public sector, good data are required to productively inform decisions on why, when, where, and how to develop and sustain irrigation and its infrastructure. Collecting reliable data in developing countries is often challenging.
Policies	A major challenge in national investment strategies will be arriving at a balance of polices that allow equitable development (for instance, policies favouring cheap imported pumps and motors) but constrain overuse (for instance, by limiting or withholding energy subsidies for abstraction).Investment will be required to more effectively monitor and regulate such private development (WB 2005).

For many developing countries, investment in irrigation will continue to represent a substantial share of investment in agriculture, but the pattern of investment will change substantially from previous decades. New investments will focus much more on enhancing the productivity of existing systems through:

- Investing in infrastructure – large and small scale irrigation systems and small land holdings
- Investing in institutions – formal and informal
- Investing in people – capacities starting from the basic education institutions to the professional irrigation and drainage system managers to farmers to decision makers

Modernization of existing infrastructure can lead to making better use of existing infrastructures should be given priority. It should be based on current and future market prospects and water service needs rather than those needs for which the system was initially designed. Modernization requires serious funding, excellent training, a design that has envisioned how the project will operate on a minute-by-minute basis, deliberate and slow implementation, and great attention to detail. There are no quick, magical solutions.

For many years FAO has been carrying out a program on "modernization of irrigation management" with the aim to help develop the capacity on how to assess and improve performance of collective infrastructure management in the technical, managerial and institutional spheres; and how to develop modernization plans. It has yielded to several standard products that are now widely used such as the Rapid Appraisal Procedure (RAP) for auditing, the MASSCOTE methodology for auditing and planning, and the MASSMUS methodology for assessing and modernizing management in the context of multiple uses of water.

The key is the capacity to first tackle the management performance in the right way, and second to improve it with appropriate approaches. While modernization represents a valid investment option in the infrastructure, other investment opportunities will have to be considered. Where possible, agricultural water investments should be targeted at small land holding in poor areas, and new irrigation projects should be designed with the needs and capabilities of the poor in mind. Promoting infrastructure and technologies adapted for smallholders is expected to have positive impact on poverty reduction.

Investment in drainage will continue at relatively modest levels, although waterlogging and salinization problems resulting from past development will continue to require remediation. Thus, there will be considerable tension arising from these financial needs compared with governments' willingness and ability to finance them.

Investing in sound irrigation institution ensures sustained returns on infrastructure investments and optimize the allocation of water to irrigation, which affect the performance of the system and in some cultures define the performance. Investing in institution includes regulatory measures, transboundary agreements, water pricing, river basin management and devolution of responsibilities to farmers through water user associations (WUAs). Institutions play an important role especially in those region heavily affected by water scarcity, especially sub-Saharan Africa. It is specifically true in areas of economic water scarcity, where there is water available in nature, but limited accessibility due to financial and human capacity constraints. Here it will be fundamental to make sustainable investments in additional water supplies (i.e. through small-scale infrastructures) that help the poor and to set up institutions for sustainably managing the resource (Molden, 2004).

Investment in building capacity of people engaged in irrigation management is central. The tools and the techniques for modern efficient irrigation practices are available but people need

to be trained to use them properly. They need to focus on management. FAO well conscious of these needs has already taken together with key partners some initiatives for raising the capacity through promotion of references centres and certification for management, and through better linkages with funding agencies.

In conclusion, investing in irrigation represents a key aspect in order to increase food production and alleviate poverty secure while reducing environmental costs and ensuring water conservation. However, it requires a long-term vision and commitment while several constraints have to be taken into consideration. Table 2 summarizes some of the main challenges that have to be taken into account in irrigation investment.

5.2 Innovations

Over the past many years, innovations in agriculture technology (precision agricultural innovations, data analytics and processing, platforms for the collection and distribution of complex data streams, and IT-driven extensions) have been on the rise. Through the use of these technologies along the entire agriculture value chain, the world can increase the productivity of its farming systems while simultaneously transforming agriculture into a source of environmental health. The crop sensing and modelling systems are able to remotely collect data such as humidity, barometric pressure, temperature, luminosity, wind speed, precipitation and soil moisture. These data, in turn, can predict the time and amount of irrigation.

Agriculture is the largest business sector which is highly driven by technologies and tools like satellite imageries, aerial imageries, GIS, GNSS/GPS, automated sensors, high tech machineries and high resolution data. The ultimate purpose of all the technologies is about optimization, precision, and to efficiently produce high crop yields. It can be noted that present innovative technology or solutions in irrigation can be used to cater the needs and challenges in different sub-sectors. These innovative technologies or solutions in irrigation can be grouped into three main categories given below:

Augmenting Water Supply

1. Irrigation utilizing fog collectors; harvesting condensed water from humid air.
2. Cloud Seeding Operation for water supply augmentation.
3. Solar and wind as source of alternative energy in small scale irrigation.

Reducing Losses

1. Subsurface Polyethylene (PE) Pipe Line Irrigation.
2. Irrigation utilizing pressure compensated subsurface drip lines.
3. Low flow spray/ Micro-sprinkler irrigation.
4. Irrigation Canal using Pre-cast method.
5. Precision land-levelling by laser-guided equipment for uniformity of flow of water into the soil.
6. Improving Operation & Maintenance of Irrigation Systems using Farmland GIS.
7. Application of drone technology as a source of valuable information about when and where to apply precise quantities of water to the crop

Managing Water Demand

1. Alternate Wetting and Drying Scheme as Water-Saving Technology.
2. Using System of Rice Intensification Method for Higher Yield with minimum water demand.

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Topic 1.2: Drivers of policy, institutional, organisational and financial innovations for better stakeholder participation in irrigation and drainage services

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Papers Presented Under

SUB-THEME 1
Key issues of irrigation and drainage in balancing water, food, energy and ecology

Topics

1.1 Roles and efforts of the irrigation sector with respect to the World water issues

1.2 Drivers of policy, institutional, organisational and financial innovations for better stakeholder participation in irrigation and drainage services

1.3 Roles of water users, private sector, government organizations and civil society in management, operation and maintenance of irrigation and drainage systems

1.4 Innovations and extension under new irrigation and drainage performance and services requirements for national water and food security

1.5 Role of irrigation and drainage for forest management


Sub-theme 1

ROLE OF IRRIGATION FOR SUSTAINABLE FOOD PRODUCTION IN RUSSIA

Liudmila Kireycheva[1]

ABSTRACT

The current macroeconomic conditions in Russia pose certain risks for the insurance of the country's food security. Russia is situated in the area of risky agriculture: 80 % of the arable lands suffer from the precipitation shortage, while excessive waterlogging is observed in 10% of the farmland. This situation is deteriorated due to the aridization of the climate. It is almost impossible to grow high-yield crop species, as well as to apply intensive agricultural technologies and adaptive-landscape systems of agriculture without land reclamation in dry years.

Now there are 4,27 million hectares (Mha) of irrigated lands and 4,8 Mha of drained lands In Russia. The average yield in the irrigated lands is 2.9 tons in grain units/ha, which is 3-4 times lower than the productive potential of soils.

The methodology basing on the energy approach which helps to increase the production potential of soils using irrigation and drainage measures has been proposed. The energy estimation includes the following calculations: bioclimatic potential; energy accumulated in the soil and in the vegetation cover. A new parameter – turbulent energy output, which is calculated as the difference between the radiation balance, energy of soil formation and energy accumulated in humus and in the crops, is used to estimate land reclamation efficiency.

This enables to predict the production potential of the agricultural land depending on the input energy in the case of land reclamation and makes it possible to use more general energy estimations instead of non-energy approach.

Using the developed technique the calculations of the soil productivity for the different natural zones of the European part of Russia were fulfilled. The greatest production potential was obtained in chernozems. It reaches 7,7 thou.grain-u/ha, and can be increased up to 10 - 12 thou.grain-u/ha under irrigation. The productivity of sod-podzolic and gray forest soils does not exceed 1.3 to 2.0 thou.grain-u/ha under natural conditions, but their productivity can be increased up to 6-8 thou.grain-u/ha under irrigation. Up to 5 times soil productivity increase can be obtained under irrigation in semi-arid and arid zones of the European part of Russia.

The suggested methodology makes it possible to allocate land reclamation projects in the zonal soils more efficiently as well as to select the most high-productive crops. The paper shows that food security can be achieved both under excess and insufficient soil moisture due to the development of land reclamation.

Keywords: Food security of Russia, production potential, land reclamation, irrigation, drainage, climate change, energy approach, the forecast of yield.

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IMPROVEMENT IN SUB-SURFACE DRIP IRRIGATED PISTACHIO UNDER SALINE WATER USE

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ABSTRACT

Pistachio is a valuable crop in Iran and is produced mostly in arid part of the country. A study was conducted in a subsurface drip irrigated (SDI) pistachio farm in Semnan region to evaluate the impact of precision irrigation and leaching management in SDI on water distribution and salt accumulation in the soil. The treatments were three irrigation management (1) irrigation based on farmers experience as control where 3 times leaching water was applied during the growing season, (2) irrigation management based on crop water requirements estimated by Penman Montieth Model (PM), and (3) irrigation management based on PM and leaching requirement (PM+LR). Water application were recorded by flow meter and soil samples were collected from different depth and distance from the trees in different pistachio growth stages. The trees faced deficit irrigation during development growth stages in control, but in others, soil water content in the root zone was at field capacity. Based on soil water content distribution in root zone, emitter line at 1 m from the row of trees and 0.40 m under the soil surface were recognized appropriate to supply crop water needs in the root zone. Soil salinity level in PM management was less than that in PM+LR. More salt entrance by irrigation was seen under PM+LR. Where irrigation management was based on PM+LR, soil salinity was about 12 dS/m within root zone area. SAR was less in PM compared to others irrigation managements. PM+LR bring better soil water content for root trees but was not effective to leach out the salinity. Sodium concentration in PM and PM+LR where less than that in control significantly. Mg concentration in control increased during the irrigation season but that was constant in PM+LR. Ca concentration in control was constant but decreased in PM and PM+LR. The was good correlation between soil water and salinity with Na, Mg and SAR but there was no a significant relation with Ca. According to the results SDI is not able to leach out the accumulated salt from the root zone by increasing the irrigation time. A complementary irrigation water by surface irrigation or rainfall event is needed to leach out the salt from the soil at the end of irrigation season.

Keywords: Subsurface Drip irrigation, Leaching, Pistachio, Irrigation managements, Semnan, Salinity.

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DETERMINING THE OPTIMAL IRRIGATION STRATEGY FOR ROTATIONAL GRAZING SYSTEMS

Birendra K.C.[1], Magdy Mohssen[2], Henry Wai Chau[3], Andrew Curtis[4], Richard H. Cuenca[5], John Bright[6], M.S. Srinivasan[7], and Keith Cameron[8]

ABSTRACT

The soil moisture content start and stop points (the irrigation trigger points), for rotationally grazed pasture are often ambiguous and imprecise. A water balance model, IrriCalc, was used to analyse the impacts of different soil moisture triggers upon the irrigation required and subsequent drainage losses over a long-term period to investigate optimal irrigation ranges within the soil water holding capacity. The analysis took into consideration rainfall and evapotranspiration uncertainties. For the analysis, available daily climatic data over a 15 year period (2000 to 2015) was used to account for climatic variability.The experiments were conducted at the Lincoln University Dairy Farm (LUDF), Canterbury, New Zealand during August 2014 to March 2016.The results showed a trigger point to start irrigation at 55 and 60% of plant available water (PAW), respectively on the shoulder (September to October and March to April) and peak (November to February) irrigation seasons, and stopping irrigation correspondingly at 80 and 90% of PAW were optimal. Adopting this irrigation strategy will help better manage environmental risk, caused by nutrient leaching loss through increased drainage, and production risk resulting from soil moisture stress. Maximising effective rainfall during the irrigation season as well as minimising drainage will help irrigatorsbetter balancingthe growing tension between water use for agricultural production and the environment.

Keywords: Threshold soil moisture content, Rotationally grazed pasture, IrriCalc, Optimal irrigation range, Irrigation and drainage, New Zealand.

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A MANAGEMENT APPROACH TO INCREASE IRRIGATED AREA AND PRODUCTION IN MADHYA PRADESH, INDIA

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ABSTRACT

About 70% of the working population of the State of Madhya Pradesh, India are directly engaged in the agriculture sector. All rivers of the State are non-perennial; hence surface water irrigation is possible only through storage of monsoon runoff water. Limited access to surface water irrigation results in groundwater exploitation. Since independence, the State has constructed many surface water resources development projects. Yet the actual irrigated area through these projects was much lower than their designed irrigation potential mainly due to lack of optimal operation and maintenance.

The most important among various actions that have taken place to overcome the challenges are- (i) speeding up completion of projects; (ii) rehabilitation of some schemes; and (iii) significant improvement in performance of existing schemes. Though the roles of actions (i) and (ii) have been very important and are discussed, action (iii) is the focal discussion of the paper. In 2010, Madhya Pradesh Water Resources Department (WRD) decided to overcome these challenges through the application of elementary water management principles. The management approach has been successful because of strong leadership, storage measurements of reservoirs, target setting based on available live storage, regular and transparent monitoring supported by a web-based management information system, pre-irrigation inspections, pre-emptive maintenance of canal systems, empowering and orienting the staff towards service delivery, rewarding good performance and eliciting cooperation from Water Users Associations and farmers.

Keywords: Irrigation Service Delivery, Irrigation Projects, Water Management, Maintenance, Water Resources Department, System Utilization, Irrigation Potential Created, Irrigation Potential Utilized.

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IRRIGATION'S EFFECTS ON FOOD PRODUCTION AND RURAL DEVELOPMENT

Ahmet Tokdemir[1], Hasan Kilic[2], Celal Kaya[3], and Mustafa Kosar[4]

ABSTRACT

This study shows how irrigation changed the Southeastern Anatolia Region (GAP Region). In the region, irrigation was planned for 1.8 million hectares land and until now only 26% is completed. In a comparative study of pre-irrigation and post-irrigation situation, the change in agricultural production and how the production diversified after irrigation were closely studied. Also, how the irrigation affected industrial development of food processing as well as rural development were considered. We further looked at how irrigation increased livelihoods of people living in the region and how that led to development of better public services. Because, as the income of people increased, better goods and services are naturally demanded by the very same population. Overall, this study shows that irrigation has a tremendous effect on food production as well as economic and rural development of a region.

Keywords: Irrigation, GAP Region, Southeastern Anatolia Project, Rural Development, Industrial Development.

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CARBON FOOTPRINT ASSESSMENT OF DIFFERENT IRRIGATION SYSTEMS

Antonio Guiso[1], Graziano Ghinassi[2], and Paolo Spugnoli[3]

ABSTRACT

Irrigation practice involves the release of large amounts of greenhouse gases (GHG). This study aims to evaluate the GHG emitted during the life cycle of three irrigation systems, with the purpose of assessing their Carbon Footprint. Life Cycle Assessment (LCA) methodology is used, according to ISO international standard 14067. Techniques selected for comparison are drip irrigation with annual laterals, 16 mm Øand 22 mm Øpipe diameter, hose reel machine with pipe 400 m long and 125 mm Øexternal diameter, equipped with travelling big rain gun and boom. Selected functional unit is the m^3 of supplied water, assuming the seasonal supply of irrigation water be equal to 2,500 m^3/ha . Analysis was carried out using the software SimaPro, with the support of the EcoInvent Database. Under the assumed scenario, the Global Warming Potential (GWP) of irrigation using annual driplines is higher than the GWP of the hose reel, equipped either with sprinkler or with boom. The impact of annual driplines is primarily due to their short lifetime (e.g., replacement is annual), while the lower GWP of hose reel gun and boom is due to their economical lifetime (e.g., 15 years) and working capacity (e.g., irrigated ha/year).

Keywords: LCA;Environmental Impacts; Carbon Footprint; Hose Reel; Dripline.

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DRIP AND PAIRED ROW PLANTING FOR PADDY CULTIVATION

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ABSTRACT

Traditionally paddy is planted in India by square method or random method. Usually farmers plant 6 to 9 seedlings per hill with standing water within a bunded field. Now a day's, due to scarcity of water, area under paddy cultivation has been decreasing gradually. To overcome the water scarcity problem we have developed a paired planting method of paddy cultivation with MIS system for better water use efficiency. With the help of 'paired row', system at 40 – 50 – 40 cm planting method with inline drip system at every 90 cm. We use 16 mm 'drip line' with 40 cm emitter spacing having 2 lph as emitter discharge. We had an economically viable system with fulfilling water requirement of paddy crop with better productivity with all befits of 'MIS','(Micro irrigation system).

In various 'trials' conducted on farmers field in Tamilnadu, Andhra Pradesh, and Punjab, we got nearly 97% saving', in water over traditional methods with increase in yield up to 30% i.e., 6.9 tons/ha with reduction in seed rate and other input costs as per climatic condition and planting time. This MIS system is suitable for most of crops with sustainable growth & desired crop rotation

Keywords: MIS, drip line, paired row, saving, trials

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INVESTIGATING GEO-SYNTHETIC (GEO-MEMBRANE) COATINGS AND PREFABRICATED MOISTURE BARRIER (INSULATION) IN IRRIGATION NETWORK CANALS AND DRAINAGE OF ARAYEZ PLAIN OF SOUTHEASTERN IRAN

Ashraf makvandi[1], Fatemeh zakerihosseini[2], Jahangir habibi[3], and Shahriar khaledi[4]

ABSTRACT

To prevent waste and pollution of freshwater and to deliver right amount of water at the right time to the right place, have always been one of the subjects in scientific water resource management. In channels, seepage loss of irrigation water is checked by adopting various options of lining, including concrete and geosynthetics. Geosynthetics are composed of compressed polyethylene materials. These are by and large chemically inert and are little affected due to weather action if adequately protected from exposure to atmosphere. That is why use of polymer covers and prefabricated humidity insulation in irrigation and drainage channels have been considered as best alternative to traditional methods by those involved in development projects around the world. In this study, the characteristics and methods of geomembrane and insulation were explained. In addition, these covers and their application in construction of irrigation and drainage channels in Arayez plain were presented, along with their advantages and disadvantages.

Keywords: Geosynthetic, irrigation and drainage channels, Arayez plain.

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EFFECT OF IRRIGATION SYSTEM ON GROUNDWATER RESOURCES IN HARRAN PLAIN (SOUTHEASTERN TURKEY)

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ABSTRACT

Irrigated agriculture is the largest consumer of groundwater resources. The interaction between agricultural irrigation and groundwater resources, both in quantity and quality,is often understood later than when the adverse effects atarts. For more efficient and sustainable utilization of the limited water resources, improved understanding of how respond to irrigation is essential.

The Southeastern Anatolia Project (Turkish: GAP) is a major and comprehensive initiative in Turkey.The GAP was a programme to develop water and land resources in the region and planned as a package that comprised 13 individual projects on irrigation and energy production on the Euphrates-Tigris basins. This project includes irrigation networks for an area of approximately 1.8 million hectares. One of the important project site is Harran Plain having the biggest groundwater resources and the largest irrigation field in the GAP region. Harran Plain has 3700 km^2 drainage area, 1500 km^2 plain area and 476,000 hectares of irrigation area. Before this project, the irrigations could potentially lead to about 2m/year decline in groundwater table. After this project application, hydrodynamic system of groundwater has changed. The groundwater level risen since 1995 in plain. In addition hydrodynamic system has been effected groundwater quality. Result show that a proper irrigation rotation system can implement and efficient water management over the irrigated areas and lead smaller groundwater change and its quality.

Keywords: Irrigation System, Groundwater, Southeastern Anatolia Project, Water Management.

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SOUTHEASTERN ANATOLIA PROJECT

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ABSTRACT

The Southeastern Anatolia Project or GAP -its Turkish acronym- is the most comprehensive, multi-sectoral, integrated regional development project ever carried out in Turkey. In 1970s the project was planned as a water resource development programme which includes the construction of 22 dams, 19 hydropower plants on the Euphrates and Tigris Rivers, the irrigation network for 1.8 million hectares of land and also to control floods and droughts in south-east Turkey. In 1989, GAP Master Plan was prepared and GAP comprised of not only water resources development projects, but also investments in all development-related sectors. It adopted the philosophy of sustainable human development and based its activities upon the principles of participation, equity and social justice.

As of 2015, within the scope of GAP, 16 dams, 13 hydropower plants (HPP) and 1032 km of main irrigation canals were constructed. The land under irrigation reached 474,528 hectares. 2.4 million hectares of land was consolidated. This is the largest land consolidation operation in the world given effect in a single. Closed drainage project covers 55,000 hectares of land, and drainage work on 40,383 hectares of land is completed. 7,416 km long part of the planned 9,000 km long drainage network is also completed.

Since the start of the project, healthcare facilities have been significantly upgraded. There were 75 hospitals and 8,488 beds in the region in 2002. In 2014, these figures were 123 and 16,895, respectively. Infant mortality rate dropped from 48.3 in thousand in 2002 to 15.9 at the end of 2014.

GAP Action Plan (2014-208) is still being implemented in the region. Its primary objectives include the completion of continuing investments, full utilization of the potential created by investments so as to accelerate economic, social and cultural development; enhancement of the competitive power of the region and carrying the project further ahead.

Keywords: Southeastern Anatolia Project, GAP, Water resource development, Competitive agenda, GAP Action Plan, Developments in the GAP Region.

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PROSPECTS FOR IMPROVING IRRIGATED AGRICULTURE IN SOUTHERN AFRICA – LINKING WATER, ENERGY AND FOOD

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ABSTRACT

Sub-Saharan Africa (SSA) faces high incidence of food and nutrition insecurity. Consequently, increasing agricultural productivity has always featured prominently on regional agenda. The Comprehensive Africa Agriculture Development Programme's (CAADP) set a target to expand the area under irrigation by at least 5 million ha by 2025. This review assessed the current status of irrigated agriculture in SSA from a water–energy–food nexus perspective, focusing on southern Africa. Gaps and opportunities for improving irrigated agriculture were also assessed in terms of the feasible limits to which they can be exploited. Sub-Saharan Africa faces water scarcity and projections show that countries in SSA will face increased physical and / or economic water scarcity by 2025. However, with agriculture already accounting for more than 60% of water withdrawals, increasing area under irrigation could worsen the problem of water scarcity. Recurrent droughts experienced across SSA reaffirm the sensitive issue of food insecurity and water scarcity. The region also faces energy insecurity with most countries experiencing chronic power outages. Increasing area under irrigation will place additional demand on the already strained energy grids. Projections of an increasing population within SSA indicate increased food and energy demand; a growing middle class also adds to increasing food demand. This poses the question - is increasing irrigated agriculture a solution to water scarcity, food insecurity and energy shortages? This review recommends that, whilst there are prospects for increasing area under irrigation and subsequent agricultural productivity, technical planning should adopt a water–energy–food nexus approach to setting targets. Improving water productivity in irrigated agriculture could reduce water and energy use while increasing yield output.

Keywords: Food security, irrigation, SADC, sub-Saharan Africa, water-energy-food nexus, water productivity.

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IRRIGATION EFFICIENCY IN THE RECLAIMED WATERLOGGED LANDS DURING DRY PERIODS

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ABSTRACT

Field studies on irrigation efficiency and vermicomposting of the degraded waterlogged peat soils are presented in the paper. Prolonged cultivation of peat soils results in loss of productivity due to the intensive mineralization of organic matter. The experimental plot is located in the area of the drainage project “Tinki-2” built in 1961-1962. The project consists of main drain and a network of open canals providing proper groundwater level. The experiment was carried out on plots 7.5 m x 15.0 m (127.5 m2) in 3 replications according to the following treatments:

1. Vermicomposting application (rate 10 t/ha) + irrigation;
2. Control +irrigation;
3. Control without irrigation.

Irrigation was applied through a portable sprinkler system. Permanent grasses were cultivated for hay in the experimental plots. Vermicomposting was by the Corporation “GreenPik” (www.green-pik.ru). Research methodology included the study of Soil characteristics, dynamics of soil moisture, the depth of ground water, irrigation rates, quality of crops and crop productivity were monitored during the 3-year experiment. In the dry periods water was applied @ 25 to 130 mm from1 to 8 times, pumping water from the open drain.

Mean crop yield of perennial grasses (hay) with vermicomposting and irrigation was 10.6 t/ha, in the 2nd treatment – 5.8 t/ha, in 3rd treatment – 3.3 t/ha. The improved comfort for plant development due to irrigation and soil humus formation intensification stimulated the development of plants. During the first two years of the experiment there was an increase in the energy accumulated in the soil humus.

Researches show a high synergistic effect of irrigation and vermicomposting application when increasing productivity of degraded and waterlogged soils. The use of drainage water for irrigation provides additional environmental benefits by reducing the volume of drainage flow discharge into water bodies.

Keywords: The system of drainage, irrigation, soil water regime, perennials, yields, peat soils.

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ECONOMIC VIABILITY OF DEFICIT IRRIGATION TO MEDICINAL PLANT IN WEST SÃO PAULO STATE, BRAZIL

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ABSTRACT

This study's goal was to determine Class A pan evaporation (ECA) influence on irrigation levels on productivity and to evaluate the economic viability of irrigation use in basil, oregano and calendula. The experiments were conducted in the field, in Presidente Prudente-SP, Brazil, being in 2006 (oregano), 2007 (basil) and 2009 (calendula). For basil the tested water depths were: T1 - without irrigation 0%, T2 - 50%, T3 - 75%, T4 - 100% and T5 - 150% ECA. For oregano, were tested: T1 - without irrigation - 0%, T2 - 25%, T3 - 50%, T4 - 75% and T5 - 100% ECA. And to the calendula, the tested irrigation depths were: T1 - without irrigation 0%, T2 - 50%, T3 - 75%, T4 - 100% ECA and the effect of organic fertilizer in two treatments: the control (without organic fertilizer usage) and the organicaly fertilized treatment. The Monte Carlo simulation was used to study the economic factors. The results led to conclude that: for the oregano crop, the irrigation levels influenced the crop's development both productivity and net income. Proper economic management was the implementation of 100% ECA water depth using electric motor during the Green Tariffor the Blue Tariff. For the basil crop an increase in net income was noticed while increasing the irrigation levels. Irrigation was considered feasible for the water depths of 75% and 100% ECA. For calendula crop the proper economic management is the use of irrigation water depth of 100% ECA without adding organic fertilizers, using an electric motor during Green Tariff.

Keywords: Water saving; Economic viability; Irrigation management.

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ADDRESSING FOOD, ENERGY AND WATER NEXUS IN A VOLCANIC AREA

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ABSTRACT

Volcanic river basins are common features in the Indonesian archipelago. In this paper, the case study is located in Progo River, on the slope of Merapi Mountain, which is one of the most active volcanoes in the world. Progo is a main river in the region, where intricate links of water uses are very complex consisted of multilevel stakeholders. Another problem that needs further attention would be the frequent volcanic eruption cycle. This situation can be categorized as wicked problems (Hadorn, 2004).The Kalibawang Irrigation channel uses the unique position in the Progo river morphology (the outside bend) as a free intake to irrigate 7,152 Ha of agricultural land. Since its first construction in 1946, the channel has been developed from 12 km to 24 km, complete with the complementing items (divider andtapping infrastructures). The channel entails several irrigation areas. The water of this channel is also used for micro hydropower generation (600KW) for a remote hamlet with 600 houses called Semawung in Bandarharjo village, Kulonprogo Regency. In the event of Merapi eruption in 2010, the intake was sealed with debris, from the mountain and it took some months of heavy maintenance works in order for it to function. However, the irrigation channel was not the only one suffering from this eruption, most of the river basins area originated at Merapi was also having the problems. It is therefore essential to mention the mitigation strategy for this area, the Sabo Dam system. It helps to protect greater damage in urban and agricultural areas. Another highlight would be the farmers' adaptive capacity towards this eruption cycle also proven to be facilitating the condition of farmlands to be operational in a rapid recovery.

Keywords: Food-Water-Energy Nexus, Volcanic Region, Mitigation and Adaptation Strategies.

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QUANTITATIVE COMPARISON OF THREE DEFENCE LINES IN REDUCING NITROGEN AND PHOSPHORUS LOAD IN RICE-BASED IRRIGATION SYSTEMS

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ABSTRACT

The concept of 'Three Lines of Defence' is used to control agricultural non-point source pollution. The three lines of defence are: on-farm water-saving irrigation, eco-channels, and constructed wetlands (irrigation ponds).

Usually, the concentration or mass load removal percent is calculated to evaluate the performance of each line based on the measured data on water quantity and quality in typical paddy fields, eco-ditches, and constructed wetlands. However, it is difficult to use the calculated values for the longitudinal and horizontal comparison of removal efficacy between different lines and different irrigation systems owing to various reasons. Firstly, the overall removal efficacy of three lines cannot equal the sum of each line. Secondly, the numbers corresponding to the removal rate were unable to indicate the nitrogen and phosphorus retaining loads of each line. Thirdly, the removal percent could not provide technical parameters for the planning and design of the 'Three Lines of Defence' system.

Real defence lines were constructed in three rice-based irrigation systems (i.e. in Zhanghe in Hubei, Qingshitan in Guangxi, and Gaoyou in Jiangsu), located in the southern China. The TN reduced by each line of defence was 9.3±7.8mg/m^2/d, 710±724mg/m^2/d, and 57.3±36.2mg/m^2/d, and the reductions in the TP were 0.22±0.21mg/m^2/d, 140±235mg/m^2/d, and 8.8±9mg/m^2/d, respectively. It was obvious that by considering the large planting areas of the paddy fields, the amounts of TN and TP reduced by the first line were significant despite its lower removal efficiency. The removal mechanisms of the second and third lines of defence were similar. They also shared high removal efficiency and a limited total removal effect. Therefore, the results from the three irrigation systems can be used as a reference for the calculation of the reasonable area allocated to each line of defence, the amounts of TN and TP loads removed by each line, and the amounts of TN and TP loads retainedon the three lines in all.

Keywords: Non-point source pollution, Nitrogen, Phosphorus; Removal efficiency, Paddy Rice, Irrigation system, China

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IRRIGATION AND DRAINAGE EFFORTS IN INDUS BASIN – A REVIEW OF PAST, PRESENT AND FUTURE REQUIREMENTS

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ABSTRACT

Indus Basin Irrigation System (IBIS) is contributing 20.9% to gross domestic product (GDP), 43.5% of total employment and more than 60% of foreign exchange earnings through its agriculture sector. Until now, the irrigated agriculture growth had been well-paced in providing the increasing food requirements of the country. This had been possible with the implementation of 61 Salinity Control and Reclamation Projects (SCARP), in addition to improving irrigation system in IBIS. But maintenance of these systems could not be institutionalized, resulting in their poor performance. Although, waterlogging was reduced from 16% to 8% in Punjab, firstly with these projects, but later on, increasing groundwater abstraction was main facilitator. But in Sindh, waterlogging still fluctuates between 25 to 60% of the irrigated area. Sustainability of current production levels is doubtful because it had been achieved at the cost of depleting the aquifers and ecosystem. Streams and lakeswhich were once fresh water sources, are noweither dryor heavily polluted, e.g. Ravi River and Hudiara Drain in Punjab; Hamal and Manchar Lakes in Sindh. In our opinion, lack of legislation and its implementation are the major factors.This paperpoints out deficiencies and lessonslearnt from the past irrigation and drainage management and recommends steps for further improvement.

Keyword: IBIS, irrigation, drainage, waterlogging, groundwater, SCARPs.

Sub-theme 1

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ROLES AND EFFORTS OF THE IRRIGATION SECTOR IN MYANMAR AGRICULTURE PRACTICE

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ABSTRACT

Agriculture has always been the dominant sector in Myanmar economy. Agriculture sector contributes 22.1% of GDP (2014 - 2015), 20% of total expert earning and employs more than 61.2% of the labour force. Presently, the country produces enough food to supply its people and export the surplus production. The total land area of Myanmar is 67.7 million hectares (Mha), the cultivable land is 26% of total area i.e., 17.65 Mha of which only about 11.95 Mha is net sown area. Most of agricultural land (about 3.96 Mha) is currently cultivated by small farmers with an average holding of 2.16 ha. Myanmar is rich in water resources in which surface water is about 108200 Mm^3 per annum from a drainage area of about 738,230 km^2 while ground water potential is about 49500 Mm^3 in eight river basins in the country. As a part of water resources utilization in agriculture sector, 581 Nos of irrigation dams have been completed, further increasing the irrigable area of 2.78 Mha by the end of March, 2016. In Myanmar, plot-to-plot irrigation is very common (based on bilateral agreement between upstream and downstream water users) and almost all canals are unlined. Hence, the water use efficiency (WUE) is only 40%. In order to improve WUE as well as environmental conservation, farmers' participation is of vital importance

Keywords: Potential water resources, Irrigation water management, Irrigation facilities, Water user groups, Myanmar.

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IMPACTS OF FURROW FIRMING AND SOWING PATTERN OF SUGARBEET ON IMPROVING WATER PRODUCTIVITY

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ABSTRACT

The Urmia lake basin in Iran faces serious water shortage. The water demand always exceeds water supply making agriculture highly vulnerable to the impact of the frequent droughts in the region. While the water shortage in this region is severe, surface irrigation methods are currently responsible for greater than 90% of the total volume of water used for irrigation within basin at a poor 35% of irrigation water use efficiency. Hence improving water productivity in Urmia lake basin is the most important strategy of the current times.

In this paper, a simple, low cost way together with an example of its use to improve the performance of furrow irrigation systems is described. Crop water use efficiency of irrigated sugar beet was hypothesized to be improved by a furrow firming and sowing pattern. This hypothesis was evaluated in Nagadeh region, Urmia for two years, using split–plot design on base of randomized complete blocks with Two different sowing pattern (A1:single rows 50 cm apart, A2: variable spacing rows; 40 cm apart on each broad planting bed and 50 cm apart on each side of furrow) and 4 firming of furrow (B1: compact of furrow before the first irrigation, B2: compact of furrow before the first and third irrigation, B3: compact of furrow before the first, third and eighth irrigation and B0: no firming furrow) in 3 replications.

Firming of furrow had no significant effect on the root and sugar yield of sugar beet. There was a significant effect (1% significant level) among sowing pattern with the product yield and the available sugar. The root yield was 44.76 and 51.74 tons in 1 ha farm that related to A1 and A2 treatments, respectively. Available sugar increased up 20.7 tons in 1 ha of A2 treatment compared with A1 and water consumption was decreased up 24.2%. The use of roller compaction of the furrows 1, 2 and 3 times (B1, B2 and B3 treatments) led to 10.6, 14.9 and 18.8 percent of water saving. Furrow compacting influence geometrical and hydraulic characteristics of the furrows. Water advancing rate and irrigation efficiency in furrow compacted by roller at first irrigation were improved by 30% and 51.7% in relation to the control.

Keywords: Urmia lake basin, furrow-firming, irrigation efficiency, water productivity, sugar beet.

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NEW GENERATION PLASTIC PIPE MATERIALS IMPROVE EFFICIENCY OF MODERN IRRIGATION SYSTEMS

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ABSTRACT

Up to 80% of water resources in most countries are used to irrigate crops mainly by inefficient flood irrigation methods. Unpredictable weather, acute water shortage and increased food demand make such a practice unsustainable. Newer polyethylene pipe materials can contribute to alleviating this problem. In drip irrigation, Aquility™, a new PE material to simplify production of drip irrigation pipes, can reduce production costs and increase its useful life, thus improving its affordability especially for farmers with small land holdings. In Egypt, the benefits of this new material are demonstrated in the peak irrigation demand season resulting in better quality consistency and simpler and more cost effective production. In India, it also encourages a wider adoption of drip irrigation systems by reducing the farmer's reliance on the local subsidy system. In U.A.E, a new approach to 'Green the desert' showcases how Aquility™ enabled Barari Forest in the desert to expand and meet its plastic waste recycling targets while producingdrip irrigation pipes of acceptable quality. The newer and tougher materials e.g., BorSafe™ High Stress Crack Resistant (HSCR) PE100 have demonstrated their worth in reducing water loss in the Valetta Irrigation Scheme in New Zealand and in restoring water to the agricultural communities around Mount Guanyin, Taiwan after the local irrigation channels were damaged by a tropical cyclone and landslides. This paper cites results from a study by Professor Alessandro Marangoni, of Bocconi University, to define the cost benefits of different water management strategies to the Italian agricultural industry.

Keywords: Polyethylene, plastic pipes, drip irrigation, durable, reduce production cost, recycling, water loss, leak-free.

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INTEGRATING AGRICULTURE AND GROUNDWATERIN PARTICIPATORY FORESIGHT ANALYSIS IN MOROCCO

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ABSTRACT

In Morocco, agricultural economies based on groundwater use increasingly face challenges of market saturation and aquifer overdraft. However, there is limited communication between the key actors of these economies to identify ways to face these challenges. A participatory scenario planning process was organized in a small territory of Morocco where groundwater is used for irrigating apple and plump trees. The process aimed to trigger a joint reflection between actors (small-scale and large-scale farms and staff from public organizations in charge of agriculture and water resources) on feasible pathways towards an economically and environmentally sustainable agriculture. Farmers' groups designed a scenario of agricultural crisis and another of economic growth that was shown to lead to groundwater overuse. As none of these scenarios were deemed satisfactory, farmers and staff from public organizations designed together an alternative scenario of economic and environmental sustainability of agricultural activities. Integrating agriculture development and sustainable groundwater use in scenario design proved useful to trigger actors' involvement in joint reflection. However, the continuation of such type of multi-stakeholder process requires the sustained presence of facilitators to organize the communication between stakeholders, but no actor plays this role in the current institutional setting in rural areas of Morocco.

Keywords: Foresight analysis, groundwater economy, Morocco, multi-stakeholder process, tree farming.

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WATER RESOURCES MANAGEMENT AND PUBLIC POLICIES FOR IRRIGATION USE IN BRAZIL

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ABSTRACT

Water resources management in agriculture aims to optimize water use for food production and domestic use. FAO has estimated an 11% increase in water demand for irrigation over the years 2008 to 2050. Public policies for irrigation use in Brazil implement guidelines, manage conflicts over the water use and fix criteria for water resources allocation and protection. This paper presents the management and public policies on water resources use for irrigation in Brazil for optimizing agricultural production. The water crisis due to climate changes and consequent environmental impacts has caused a re-think on water resources management policies. In Brazil, the public policies for the water resources management aim to balance both of the region development and environmental impacts of water use. The Brazilian National Water Resources Council, created in 1998, mediates water use's rules for many users, implements guidelines for the National Water Resources Policy, arbitrates water conflicts, approves projects of watershed committees and establishes criteria for water resources allocation. These practices promote the sustainable water resources use and substantiate the water as a public good, limited natural resource with economic value and multiple uses. The agricultural productivity increase studied by the Ministry of Environment is a result of no-conflict water resources use, environmental legislation and ecosystems' diversity that supported the sustainable capacity increase of irrigated agriculture. ANA ensures that the water resources management for irrigated agriculture has favored food production's increase and lowered prices when compared to products from non-irrigated areas. In 2013, the government established the Program for Irrigated Agriculture stimulating irrigation schemes development and the irrigated agriculture management restructuring. This program has enabled the management, operation, maintenance, revitalization, regulation and support to ensure for the irrigated areas an operational management. According to the Intergovernmental Panel on Climate Change, that evaluated temperature and precipitation projections from 2010 to 2099, it was confirmed that irrigation is an adaptive technique that adds value to the land, to the production and ensures food security. Facing the increasing world's population and the water crisis in several world regions, the food production sustainability and the adoption of effective ways to conserve water resources, especially the development and management of irrigation should be given priority to promote water saving.

Keywords: Water saving, Agricultural production; Tax breaks.

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SUSTAINABLE IRRIGATION WATER MANAGEMENT FOR IMPROVED WUE: CONTEXT OF INDIAN NATIONAL WATER POLICY 2012

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ABSTRACT

Improving the performance of completed Major and Medium Irrigation (MMI) schemes has been the main focus of the National Water Mission (NWM). It set a target of increasing the Water Use Efficiency (WUE) by 20% in the current plan period. WUE studies carried out by the Central Water Commission (CWC) on 30 MMI schemes indicate that in nine schemes WUE was less than 30% and the average was 38%. The NWM targets the average figure to become 46% by the end of the plan period. Irrigation project-wise efforts are needed on (A) Water Management under Scarce Conditions, (B) Large Scale Implementation of Water Saving Technologies, (C) Promotion of Micro Irrigation in canal commands, (D) Incentivizing Water Saving Concepts like virtual water and water credits and (E) Multiple Uses of Water and Economic Value. Irrigation projects are serving important sectors apart from irrigation. It needs to accurately mapped and estimated the water utilized in various sectors and their economic contribution for economy. FAO has developed a tool called MASSMUS Application for evaluating Multiple Uses of Irrigation Projects.

Keywords: Sustainable Development, Water Use Efficiency, Virtual Water, National Water Policy.

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DRIVERS OF POLICIES AND STRATEGIES FOR OPTIMIZING IRRIGATION WATER MANAGEMENT IN IRAN

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ABSTRACT

Limited water resources in Iran have been a constraint for the further development of agriculture. About 90% of agriculture crops are produced in the irrigated lands. In this situation strong policies and strategies are needed to optimise the use of limited water and support food production. Iran Vision 2025 is the document that guides the social and economic development of the country in the long term. Therefore, the current and future endeavours on research, credit, economy and industrial programs shall follow the realization of these national aspirations during the vision period. The strategy includes specific targets to achieve higher water productivity, groundwater management and agricultural water share.

According to Iran's National constitution all waters is of public interest and under responsibility of government. Based on Iranian water sector law the use of water resources requires obtaining water use License. Public water authorities shall issue optimum water use license for the agricultural water users according to the criteria declared in the fair water distribution law (1982). An extra 10% water use in agriculture shall be charged one and half time the official fee. Pricing policies play an important role in water demand management and its optimal allocation. Current prices policy for agricultural water depends on crops, source of water supply (surface or groundwater), and area to be irrigated. So to improve the performance of irrigation schemes, modernization programme has been taken up at all levels, bottom to up, from on-farm to irrigation canals and schemes and to national level in Iran. Adoption of sprinkler and drip irrigation methods is being encouraged to minimize losses in water application in field. Since the installation costs are high for these systems, central and state governments are providing subsidies to farmers as an incentive to adopt these systems. The policies and strategies applied to prevent water loss and encourage water savings in irrigation would be discussed in the article.

Keywords: Water Use License, Water Saving, Water Charging, Allocation.

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TRANSITING FROM AGRICULTURE TO AGRIBUSINESS – A MODEL FOR INCLUSIVITY AND SUSTAINABILITY FOR PADDY FARMERS

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ABSTRACT

Driving Malaysia towards a developed Nation is the Economic Transformation Plan (ETP) that aims to increase the Gross National Income (GNI) from RM 23,000 in 2009 to RM 48,000 per capita by 2020. It is also to increase opportunities for higher value jobs, for sustainable development. The issues of paddy farming still remain after all these years – small farms, aging farmers, the need to sustain paddy production for food security in a transiting economy and low water productivity. Under the ETP are the Entry Point Projects (EPPs) that are projects designed within each of the 10 National Key Results Areas (NKRAs). The theme for Agriculture NKRA is "Transiting from Agriculture to Agribusiness" and is in line with the Ministry of Agriculture and Agro Industry's theme that "Agriculture is Business". To address those persistent issues of paddy production affirmatively, is the EPP10: Scaling-up and strengthening of paddy farming in the Muda Area. The idea is to agglomerate individual farms and to increase average yield to 8 tonnes/ha by 2020. The targets are for a GNI of RM1 billion and the exit of 27,500 farmers. Replicating this is the EPP11: Scaling up, strengthening paddy farming productivity in other areas. The initial focus will be on incentives to encourage outsourcing of land management. The targeted GNI here is RM1.4 billion and for a reduction of 9,600 low-value jobs.

This is the first time for a "Game Changing" effort that includes exit plans for individual farmers through a compensation package, encouraging the formation of Special Purpose Vehicles (SPVs) formed either by farmers or private sector investors to produce paddy commercially and intensification of tertiary irrigation facilities. The EPP 10 began in 2011 with the target area of 50,000 ha (about 50% of the total Muda paddy area). Implementing this is not without challenges. This paper shares the concept of EPP10, the challenges faced and efforts for refining the approach. This includes revitalising the Water User Groups (Water User Associations) and plans for performance assessments and irrigation efficiency improvements.

Keywords: Irrigation, Paddy, Exit Plan, Transition, Agribusiness, MADA, Water User Group, Water User Association, Malaysia.

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EQUITABLE DISTRIBUTION OF WATER IN UPPER GODAVARI SUB BASIN: A CASE STUDY FROM MAHARASHTRA

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ABSTRACT

Maharashtra state of India is located in the semi-arid climatic zone where assured irrigation supply is essential for optimal crop growth. Presently, only about 20% of the state's cultivable area is brought under irrigation. Since last four decades, the state government has been giving emphasis on water resources development by constructing large and small dams. The state now has the highest number of dams in the country creating a storage capacity of about 40 billion cubic meters. About 70% of surface water storages are used for irrigation. In absence of integrated approach at basin/ sub-basin level, there has been lopsided development and use of water resources in the state. As the basins/ sub-basins are getting closed due to over usage of water, conflicts among upstream and downstream stakeholders and different categories of uses are escalating. Maharashtra Water Resources Regulatory Authority was established in 2005 to regulate and ensure equitable distribution and utilization of water resources in the state. Godavari basin, the second largest basin in India covers about half of Maharashtra's geographical area. Maharashtra part of the Godavari basin is divided into 27 sub-basins. The Upper Godavari Sub-basin is one of the most developed basin in terms of agriculture, urban and industrial growth in the state. Many irrigation projects were constructed in the sub-basin to meet the growing water demand for irrigation, domestic and industrial uses. As the water demand has continually been increasing compared to the availability, the sub-basin has been experiencing water scarcity situation frequently leading to conflicts for water sharing between upstream and downstream stakeholders as also among different categories of uses. The case study presented in this paper briefly describes the role played by the water regulatory authority in addressing and resolving the dispute by framing guidelines towards sharing the available water between upstream and downstream reaches of the Upper Godavari sub-basin.

Keywords: Upper Godavari sub-basin, equitable allocation of water resources, Water Resources Regulatory Authority, irrigation and non-irrigation uses.

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THE DILEMMA OF GROUNDWATER CONSERVATION IN MEXICO

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ABSTRACT

Annual groundwater recharge in Mexico is 92757 million cubic meters (Mm^3). A volume of 18045 Mm^3 is used for agricultural purposes, legally provided by CONAGUA to irrigation users granting 127526 temporary Concession Titles distributed in 653 aquifers across the country. Nowadays, there is a record of 106 overexploited aquifers. Only 80 aquifers have an overexploitation of 5392 Mm^3/year, considering as exploitation or intensive exploitation, when the extraction is greater than 10% of the annual recharge. The Federal Government of Mexico through the Federal Electricity Commission (CFE) support farmers by granting a special rate for the electricity used in pumping systems. However, lack of supervision has provoked a rapid overexploitation of groundwater. This challenge must be overcome in the short and medium term to avoid a water catastrophe for future generations. Groundwater provides a third of the food produced by irrigated agriculture, however, balance rests on a decision to use only biddable water of each aquifer and in each well, to measure directly or indirectly the water extracted by pumping systems and to only support with an electric rate those who comply that established in the National Water Law (NWL). Electric energy is the basis of pumping systems, which means that both CONAGUA and CFE should reconsider their policy of monitoring and charging for the use of such energy; this charge should be made directly to users that exceed the Concession Title though and extra charge and restricting them and ultimately, removing the service to those who violate the law. Currently, the Secretariat of Agriculture, Livestock, Rural Development, Fisheries and food (SAGARPA), under the Federal Government, pays CFE the subsidies of electricity used in the system of agricultural pumping (including the legitimate and the overexploited volume)' However, this causes a huge waste of public funds. This has contributed indirectly to the overexploitation of many aquifers and breaks the balance between paying energy for sustainable purposes of exploitation of groundwater and meets the needs of food production. This requires the development of a new policy of water resources development and use such that abuse of high-cost electric power is halted and overexploitation of aquifers in Mexico is reversed.

Keywords: Irrigation, Overexploitation of water, Water users, Policy.

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IWRM FROM CONCEPT TO PRACTICE: USEFULLNESS & LIMITATIONS IN MANAGEING FLOOD-BASED FARMING SYSTEMS

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ABSTRACT

The Spate Irrigation Network Foundation (SpNF) is promoting Flood-based Farming Systems (FBFS) for multiple use including crop production, agro-forestry, domestic and livestock water supply, groundwater recharge and climate mitigation. This focus on multiple use make the concept of IWRM very relevant. The questions remaining are: (a) to what extent can the IWRM be a useful tool in practice? (b) What are the major limitations and (c) how can these limitations be addressed? These questions are central to this paper and the Harnessing Foods for Enhanced Livelihoods and Ecosystem Project that is being implemented by the Hydraulic Research Centre, Sudan. The project has employed RIBASIM modelling for optimum allocation and multiple use of the available floodwater resources as well as Modflow to assess groundwater recharge. Further, the impact of the floodwater allocation on agricultural production has been analysed using AquaCrop software. The project also identified two major challenges facing the implementation of IWRM: (1) integrating gender priorities, and (2) suitability and enforcement of the exiting water governance.

Keywords: Adaptation strategies, Irrigation schemes, Climate change, Regional Climate Models, Crop water requirement, Mexico.

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ANCIENT CHINESE IRRIGATION PROJECT MANAGEMENT AND ITS CONTEMPORARY ENLIGHTENMENT: A CASE STUDY OF CHATAN WEIR

Lihui Gao[1], Ning Chen[2], and Kunlun Ding[3]

ABSTRACT

A lot of ancient irrigation projects have been executed in China for thousands of years and some of them still work today, playing a vital role in crop production. The evolution of the management of Chatan irrigation project is a representative case. The project is firstly transformed from family management into rural clan management, and then gradually changed from being constructed by the civilians alone to the civilians running the project under the government's supervision and to the officials and civilians jointly running the project. The running of Chatan irrigation project has at the same time completed the transformation from family business to a social public affair. During the process, the role that the government performs gradually evolves into one that makes decisions on the organization and management of the project as well as on the systems for organizing and managing. The government plays an increasingly important role in resolving the disputes over water using among the civilians as well as ensuring the sustainable operation of the project. The experience of management gained from Chatan irrigation project provides enlightenment about the management of irrigation projects at present times.

Keywords: Management, Chatan weir, irrigation projects.

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PADDY FIELD AREA CONSOLIDATION FOR SAVING RESOURCES AND FOR BETTER YIELDS IN SRI LANKAN SOCIO-ECONOMIC CONTEXT

G.M.C.A. Perera[1]

ABATRACT

Main paddy farm families in Sri Lanka have been splitted into sub families, making the family-owned farm lands fragmenting into small parcels. This has created problems in the seasonal cultivation activities in time, problems among themselves, water sharing issues, water management and also issues in using farm machinery in small land plots. This shows a cross section of status of future farmland, indicating the future image of the Sri Lankan farmland sizes and socio economic problems related land fragmentation. Because of these issues, there are land tenure problems, issues in using of farm machinery in small paddy areas, labor shortages in cultivation, seed paddy & fertilizer issues etc.

In Sri Lanka paddy fields under a major schemes are divided into tracts. One tract is of about 500-1000 acres. For each tract there is one or two farmer organizations which look after the member farmers in cultivation. Irrigation water is received from Irrigation department through distributary & field canal network to their farmlands. And farmer organizations' activities are handled by Project Manager of Irrigation Management Division (IMD) of particular scheme.

Under the study it is expected to have consensus survey with farmers for consolidation of paddy land plots in a particular larger area in a tract, that can be handled and the manner in which for using of large machineries more effectively in farmlands for enhanced cultivation practices. Also it is hoped to examine the possibility of handing over the area to a diligent group which can do the cultivation in a fruitful manner to have better yields and reduced costs for cultivation.

Keywords: Paddy, cultivation, water management, farm machinery, land Fragmentation, farmer organizations, Irrigation water.

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ROLE OF IRRIGATION AND DRAINAGE IN SUSTAINABLE FUNCTIONING OF THE AGRICULTURAL SECTOR IN UKRAINE

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ABSTRACT

Soil and climate in Ukraine are favorableto grow many crops, but the uneven distribution of water resources makes agriculture difficult. Thus, in the South of the country, in many cases, lack of rainfall in the growing season resulted in significant crop losses.The north and northwest part of the country is prone to excess rainfall that leads to oversaturation of soils, and in many cases even to flooding, which also results in crop losses.Thus, the agricultural sector of Ukraine needs intensive reclamation activities: irrigation in arid areas and drainage in the wetlands.

The problems related to the construction of irrigation and drainage systems, reconstruction and modernization the existing ones, restoration of their functioning in connection with the reform of the agricultural sector and the transition to new forms of management are covered in this article.

Keywords: Irrigation, drainage, agricultural sector, water productivity, reconstruction and modernization.

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THE NEW CHALLENGES AND NEW DEMANDS FACED BY CHINA'S DEVELOPMENT OF IRRIGATION AND DRAINAGE

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ABSTRACT

Ever since the beginning of the 21st century, irrigation and drainage in China has been facing the new challenges. The simultaneous development of information technology, industry, urban areas and agriculture, has brought in new and higher requirements on irrigation and drainage. The new challenges faced by irrigation and drainage include: the increasing population, decreasing farmland; declining irrigation area; and reduced but older rural population. The major problems encountered by irrigation and drainage have been summarized and the causes for these problems have been analyzed from the aspects of finance and taxation policy, labor allocation, legal environment, engineering techniques and land operation system and the policy guidelines of the irrigation and drainage in the new era have been put forward.

Keywords: Irrigation and drainage; situation change; new challenges, existing problems; policy and suggestions.

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TOWARDS IMPROVING PARTICIPATORY WATER MANAGEMENT AND INFORMATION MANAGEMENT TOOLS WITHIN WATER CONSUMERS ASSOCIATIONS IN UZBEKISTAN

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ABSTRACT

The institutional set-up of water management in Uzbekistan comprises different stakeholders. The dominant stakeholder is the Ministry of Agriculture and Water Resources, which plays the key role to implement state water policy and to coordinate the other water management bodies. At the national level, the Main Water Resources Administration is managing irrigation and drainage infrastructure. At regional and district levels, Basin Irrigation System Administrations are responsible for water supply through Irrigation Systems Administrations, whereas Water Consumers Associations (WCA) are the link with the farmers, expected to play an important role in on-farm irrigation water management. However, the actual role of WCAs and their cooperation with water users is weak, which leads to ineffective water use and management of the resource at grass-roots level. Farmers suffer from uncertainty in water delivery under the current system of water management. There is evidence that use of mobile phone technology as information flow and communication management tool in irrigation water management plays an important role in improving organizational activities of water management within Water Consumers Association in Uzbekistan. Information exchange is important for better informed decision-making process within WCA. Ultimately, improving stakeholders' participation in decision-making processes should improve current on-farm water management in Uzbekistan.

There is an urgent need to adopt such a participatory approach in line with the use of information management tools, such as mobile phones – for better communication and data sharing to support on-farm irrigation management and decision-making processes. The current research paper is aimed at demonstrating the steps towards improvement of participatory water management facilitated by the use of mobile phones as information management tools at Water Consumers Association level in Uzbekistan. This paper presents the process of implementation of participatory research steps and some preliminary outcomes obtained from use of participatory tools.

Keywords: Participatory management, Information management, Water Consumers Association, Uzbekistan.

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THE SOUTHEASTERN ANATOLIAN PROJECT (GAP – RDA) AGRICULTURAL TRAINING AND EXTENSION PROJECT (GAP-TEYAP) FARMER ASSOCIATIONS CENTERED PLURALISTIC EXTENSION MODEL (1.4)

Mehmet Açıkgöz[1], Nusret Mutlu[2], Celal Kaya[3],
Fatih Bozgeyik[4], and Reşat KÜÇÜK[5]

ABSTRACT

Production speedup in agriculture which has a very important place in the economy of our country and region, is dependent on expanding irrigated farming fields together with the use of technology. In this regard, investments in irrigation projects have great importance to increase agricultural productivity and production. The most important factor that impacts the effectiveness and success of costly irrigation projects can be thought as the social and economic development of the farmers. For this reason, farmers training through agricultural training and extension programs about disseminating irrigation technologies, effective use of water, and irrigated farming techniques is highly important. The social structure of the region, together with the rapid increase in the amount of irrigation fields due to GAP Action Plan, and the emergence of new production and marketing trends around the globe emphasize the importance of and need for the training and extension project. For this purpose, in 2011 GAP Regional Development Administration (GAP RDA) has started GAP Agricultural Training and Extension Project (GAP TEYAP) to be applied all around the region. This project aims to point out how to fill in the lacked services regarding training-extension that farmers need. In this regard, the extension model has been developed where the farmers and farmer unions are actively involved, and it has been implemented as the second phase since January 2014.

Keywords: Agricultural Extension and consultancy Services, GAP Regional Development Administration (GAP RDA), GAP Agricultural Training and Extension Project (TEYAP), Pluralistic Extension Model (Model), GAP Action Plan

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AFRICA CAN LEARN FROM THE IRRIGATION MANAGEMENT EXPERIENCES OF JAPANESE LAND IMPROVEMENT DISTRICTS/LIDS

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ABSTRACT

In Africa, rainfall variability and lack of irrigation cause moisture-stress, and being accompanied with the old production and input technologies, they undermined structural output and yields. There were attempts to redress the problem of low structural yield and output in Africa by investing in small and large-scale irrigation since 1970s, but due to several reasons a number of these irrigations schemes failed. One of the reasons is a lack of proper scheme management mainly O&M. Recently, African governments seem to pay attention to irrigation management and the experience from Japanese LIDs could contribute towards sustaining them. With the objective of identifying experiences of irrigation and its management, the study used a method of comparing and contrasting the participatory irrigation management (PIM) experiences of Japanese LIDs to the experience of the irrigation and management by WUAs in Africa. To achieve the objective, the authors gathered qualitative information from three LIDs and compared them with similar information from a few African countries. The findings indicate that institutional and technical gaps hamper the success of Water Users Associations (WUAs) in Africa. These gaps include: (1) premature water policies and acts in Africa. (2) The WUAs in Africa are created with a top-down approach and as such not participatory though they are assumed to be so. (3) Institutional support at various levels, including government support and urban-rural linkage in Japanese LIDs, are missing in Africa. (4) LIDs face little market risk, and cooperative input supply and output market contribute to the success of LIDs, indicating that not only irrigation fundamentals but also production inputs (e.g. R&D, seed technologies) are essential elements to sustain irrigation. (5) Urban expansion overtakes irrigation land and its expansion rate is not considered in initial irrigation investment- Africa should not repeat such mistakes in its irrigation investments. (6) Area-based water-charges, though it has water saving limitation, is accompanied by soil-water conservation mechanisms in LIDs. The soil-water conservation mechanism sustained irrigated-rice production for centuries in Japan, which is another experience that African countries have to pursue.

Keywords: Irrigation, Experience, Land Improvement Districts/LIDs, Japan, Africa.

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NATIONAL AND GLOBAL CENSUSES OR SATELLITE-BASED ESTIMATES? ASIA'S IRRIGATED AREAS: IN A MUDDLE

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ABSTRACT

Asia holds 70% of global irrigated areas and accounts for 62% of world food demand. Existing datasets for irrigated areas, collected by national and international agencies often vary from each other. In this study, a detailed comparison is made within national and global statistics including global irrigated area maps (up to 250m).Variations in data was scaled using statistical tools for national datasets and satellite based estimates. Results of the study show that there is a high variation between satellite based estimates and national statistics for several countries, e.g. India (129%), China (119%), Nepal (103%), Thailand (124%), Indonesia (64%), Vietnam (86%) and Japan (88%). Analysis of the reporting mechanisms of countries under study show that they mostly rely on traditional statistical methods to collect data, e.g. sample or complete surveys based on interviewing farmers, with limited field verification. We used a scoring system to quantitatively scale the reliability of the processes in order to investigate the inconsistency in reported numbers. Moreover, spatial dispersion analysis showed the difference of area estimates for small and large irrigation schemes as 27% and 144% higher than the national statistics respectively for Asia as a whole. The implications of uncertainty came up with some critical questions, i.e. how much is the actual annual land productivity? What is the actually utilized irrigation potential and how far is that from national target? Consequently this study puts forward some critical recommendations to improve the existing reporting systems for irrigated areas information and to look for linking satellite data with the ground truth.

Keywords: Food Security, Data Uncertainty, Agricultural Census, Irrigation Census, FAO Statistics, Remote Sensing, Irrigation Potential, Land Productivity.

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TENANT COLLECTIVES IN THE EASTERN GANGETIC PLAINS – A NEW MODEL FOR BOTTOM UP IRRIGATION AND LAND MANAGEMENT FOR MARGINAL WOMEN FARMERS

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ABSTRACT

The Eastern Gangetic Plains of Nepal and India has for decades remained one of the most peripheral corners of South Asia. Deeply inequitable landlord-tenant relations have blocked irrigation development in this densely populated region, despite abundant groundwater supplies. Tenant farmers represent a significant portion of the farming population comprising over half of cultivators in some villages. Tenants face considerable constraints in accessing groundwater. These include small or scattered holdings and high rents paid to landlords which make pumping prohibitive, not to mention tenure insecurity which discourages fixed investments in tubewells and other infrastructure. In this context, male out-migration is increasingly essential for households to meet their subsistence needs. The women who stay behind are left responsible for the farm, yet limited access to irrigation makes them particularly vulnerable to droughts and other climatic extremes.

This paper showcases an innovative model to improve irrigation access for tenant farmers through collective production – a model currently being piloted in Bihar, the Nepal Tarai and West Bengal through a consortium of government and NGO partners. The strategy includes mobilising groups of landless women to take a joint lease for a plot, and then sharing labour, irrigation costs and profits. Groups have been supported to use water and energy efficient technology such as solar pumps and micro-irrigation systems. So far the model has surpassed expectations. By operating a contiguous plot and sharing costs, investments in pumping become feasible. Labour pooling helps farmers overcome labour shortages which have escalated due to migration, and allows a division of responsibilities which saves all group members' time. Women's empowerment and capacity to bargain with landlords and service providers has also grown considerably. Although work is still to be done to optimise the model, it has the potential to revolutionise smallholder irrigated agriculture and gender empowerment in the region.

Keywords: Land tenure, Micro-irrigation, Collective farming, Nepal, India.

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IRRIGATION REFORM IN UKRAINE: ORGANIZATIONAL AND LEGAL ASPECTS

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ABSTRACT

The rehabilitation and efficient utilization of the existing potential of the irrigation systems of Ukraine requires resolution of institutional and organizational issues. On the background of the global climate changes, the existing natural and social conditions make the role of irrigation stronger in achieving sustainability of the arable farming and transformation of Ukraine into one of the world's leading food donors.

The State Water Agency of Ukraine (SWAU) currently implements the state policy in development of water management and amelioration of lands, besides management and operation of the relevant state owned assets. The currently existing structural form of management offers no incentives to reform the system itself, therefore an external intervention is needed to push the reform and make relevant efficient managerial decisions.

Amendments to the Ukraine's legislation in force are needed in order to introduce a clear legal framework for both establishment and functioning of the water user associations (WUAs).

The reform of the Ukraine's water management sector besides preserving the existing functionality of the irrigation systems should also aim at a gradual transition to the most common market principles.

Once water consumers have been structured into WUAs, the latter could further acquire features of legal entities or establish legal entities to become retail water suppliers, to maintain and operate on-farm irrigation systems and to possibly own those systems.

Keywords: Reform, irrigation sector, management, modernization, rehabilitation.

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INNOVATIVE PARTNERSHIPS: AN ANSWER TO THE TRAGEDY OF THE COMMONS

Laura Schroeder[1]

ABSTRACT

The tragedy of the commons is an economic theory of a situation within a shared-resource system where individual users acting independently and rationally according to their own self-interest behave contrary to the common good of all users by depleting that resource.

The concept is based upon an essay written in 1833 by the Victorian economist William Forster Lloyd, who used a hypothetical example of the effects of unregulated grazing on common land in the British Isles. This becme widely-known over a century later due to an article written by the ecologist Garrett Hardin in 1968.

In the 1960's William F. Schroeder lectured on the tragedy of the commons related to the failure of federal land use management agencies to manage the public lands in the United States. One can easily apply this theory to water infrastructure in the United States.

Water users traditionally pay and allocate funds on an annual basis for water delivery but find it difficult if not impossible to raise funds for the maintenance, repair or replacement of century old infrastructure. Since there is no "road tax" received from those consumers who benefit from the food produced from irrigated infrastructure, the infrastructure is often patched year after year until it fails.

The federal government through the Bureau of Reclamation and the states through their respective water agencies continue to seek legislative funding for major repairs. However, because the increasingly urban public "sees" little or no direct benefit from irrigation infrastructure funding, obtaining funding from political elected is near impossible. A group of farmers in rural northeastern Oregon, facing decreasing groundwater supplies through shorter water allocations in a critical groundwater area as well as limited surface water supplies brought by Oregon's political closure of diversions from the Columbia River, developed innovative partnerships for the purpose of funding the maintenance and expansion of irrigation infrastructure. Partners for this project include federal, state, and local governments including two Port authorities, one City, and irrigation districts.

This paper will discuss the formation of these partnerships and five year history of successes and disappointments faced by these farmers who will likely deliver the first irrigation water to new lands in northeastern Oregon during the summer of 2016.

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A STUDY ON IMPROVING SAND TRAP IN A LARGE SCALE OF IRRIGATION SCHEME

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ABSTRACT

Sediment in the canals is a major problem in ensuring smooth water distribution in a large scale of irrigation systems and reduces the system efficiency.

River water contains huge amount of bed load and suspended sediment. When the sand enters into the canals, the canals cross-section and its conveyance are reduced. In order to recover its function, sediment must be removed. However, during the sediment removal, water delivery must be stopped and it also requires huge expenditure.

Sand trap plays the significant role to prevent or minimize the sedimentation in the canal. Sand trap must be designed in order to reach the goal and increase the irrigation efficiency. The suspended sediment can be removed considerably if related devices are quipped and managed adequately.

A study was undertaken to (1) understand the problem and the performance of designed sand trap structures on RMC of the Mae Lao Irrigation Scheme (MLIS); and (2) propose the improving sand trap performance. It will study the design of sand trap structures. The study on parameters will include distribution of flow velocity, sediment transport and trapping. The efficiency of sand trap will be examined in the field.

Keywords: Sand Trap, Sediment removal, Trapping and flushing effectiveness, Improving irrigation efficiency.

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SOCIO-ECONOMIC ISSUES AND NATIONAL WATER POLICY LINKAGES FOR SUSTAINABLE DEVELOPMENT OF IRRIGATION IN INDIA – A STUDY OF HIMACHAL PRADESH

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ABSTRACT

This paper intends to: (i) find out the existing status of water availability and use; (ii) identify gaps in demand and supply of water at farm level and (iii) suggest policy implications for making water available and its use on sustainable basis. Data analyses have revealed that the Per capita water availability in India has reduced progressively at (-) 19.20 % annually during the last six and a half decades (1951-2016), forcing her to become a water-stressed country. Declining Per capita land holding due to population growth, accompanied by water stress has lowered crop productivity in India, including her hill states. The on-going irrigation development programs in the state have enabled irrigation for about 20 per cent of total cropped area and at field level total irrigation development weighted index has been worked out to be 0.44 considering different multi-disciplinary variables pertaining to psychological, educational, social, economic, institutional, technical and environmental issues. Water demand and supply gaps at farm level have been found to be 76 per cent. A critical review of different water related projects from economic considerations has revealed unanswered questions, which need to be addressed scientifically. Socio- economic issues show deviations of the policy contents at implementation level. The important details of important multi-disciplinary steps involved in micro and macro level planning of water resource/irrigation in the country as well as state to fulfil the basic objectives of water conservation and its' efficient use on sustainable basis have been interpreted in line with national water policy.

Keywords: Water stressed, demand, supply, weighted index, multi-disciplinary, water policy.

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SIMULATING HYDROLOGICAL PROCESSES IN AN AGRICULTURAL WATERSHED USING SWAT MODEL

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ABSTRACT

Estimation of sediment yield is needed to study the reservoir sedimentation, river morphology and taking up any soil and water conservation measures. Soil erosion due to accelerating runoff poses a serious threat to the long term sustainability of the fragile Chotanagpur landscape characterized by subsistence farming. The study was aimed at delimitation of the zones of high runoff and consequently soil erosion in the agriculture dominated Chotki Berghi watershed in Eastern India. Identification of such zones could help in the implementation of better land management practices. The Soil and Water Assessment Tool (SWAT) was applied to simulate stream flow and sediment yield. The model was calibrated for the period 2004–2006 and validated for 2007–2008. Nine highly sensitive parameters were identified of which base flow alpha factor was the most sensitive. The results were satisfactory for the gauging station with R^2 = 0.75 and NSE = 0.78 for calibration and R^2 = 0.62 and NSE = 0.68 for validation period. Sub-basin 5 contributed highest sediment load to the outlet and thus need immediate attention. The SWAT model could be effectively used to predict stream flow and sediment yield in order to effectively design irrigation system and water resources planning and management at large scale.

Keywords: Hydrologic modelling, SWAT, SWAT-CUP, sediment yield, Sediment distribution, Jharkhand, India.

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ANALYSIS OF THE TRADITIONAL *MIRAB* SYSTEM AND POINTERS FOR ITS PRESERVATIONIN AFGHANISTAN

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ABSTRACT

Mirab is a person or a groupthat provides irrigation operation and maintenance services in traditional irrigation systems in Afghanistan and nearby countries. The *Mirab* is nominated by land owners andhe mobilizesbeneficiary communities for participatory collective works. *Mirab* is authorized to cut illegal diversion of water from canal, identify and introduce defaulters to the communities and authorities.In-depth analysis of the mirab system in Afghanistan reveals that it entails some distinct characteristics in terms of: responsibility, apprenticeship process, flexibility of organizational structure, basis and process of water allocation and distribution, resource mobilization for O&M and process for conflict resolution.

At present, about 65 % of the irrigation systems in Afghanistan are operated by the *Mirabs*. This traditional system, however,has been facing many challenges due to the effects of modern day economics, changing values and norms of the society. With increasing urbanization and migration into urban centres, many younger people are leaving rural areas and deviating from practices like free labour contribution which forms the basis of the *mirab* system. Moreover, the *Mirab*system does not have legal recognition in the current institutional framework. The Water Law of Afghanistan focuses on more recent formal organizations like the Water Users Associations and Irrigation Associations as legal community institutions for the purpose of management of water resources.

This paper explores the intricacies of the *mirab* system both in terms of its evolution and its inherent characteristics reviewing the available literature and authors' observations from several case studies of irrigation systems. It then presents an analysis of its present status and outlines the major challenges being faced. The paper also attempts to describe how the system can be preserved and integrated into formal organizations so that valuable services that it was providing can be sustained by making it compatible to the present day needs and requirements.

Keywords: *Mirab* system, operation and maintenance of irrigation systems, sustainability, Afghanistan.

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EXPLORING WAYS TO INCREASE PUBLIC INVESTMENTS IN AGRICULTURAL WATER MANAGEMENT AND IRRIGATION FOR IMPROVED AGRICULTURAL PRODUCTIVITY IN SOUTHERN AFRICA

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ABSTRACT

The paper explores the current challenges and opportunities for increasing public investments in agricultural water management and irrigation for improved agricultural productivity in Southern Africa. The analysis was based on a critical review of literature and assessment of the national agricultural investment plans and agricultural/ water policies in the study countries. Despite the potential to improve agricultural productivity, irrigation does not currently play a significant role in Southern African agriculture. There have been efforts at the continental, regional and country levels to promote investments in agricultural water management and irrigation to improve and sustain agricultural productivity in Southern Africa. However, despite these commitments, actual implementation has been a challenge and the first five years of national agricultural investment plans have passed or are now coming to an end without much progress made regarding actual investments. Lack of adequate resources and institutional capacity have been some of the challenges affecting implementation of the investment plans to meet commitments in sustainable land and water management. Changes in climate also pose challenges for plans to increase area under irrigation in Southern Africa. Therefore investment planning for agricultural water management and irrigation should look beyond expanding area under irrigation to address other issues such as sustainable water use, efficiency in irrigation systems and investments in water storage to sustain irrigation investments and cropping systems in droughts and dry seasons. Overall, as countries plan for the second phase of the CAADP programme, there are opportunities to ensure that investments in agricultural water management and irrigation and complementary technologies are prioritized and allocated adequate resources for implementation.

Keywords: Agricultural water, irrigation, investment, productivity, Southern Africa.

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CHALLENGES TO THE CONSERVATION OF SUBAK SYSTEM AS WORLD CULTURAL HERITAGE IN BALI

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ABSTRACT

Subak in Bali is believed to have existed from earlier than the ninth century. Throughout this long period, *Subak* has been successfully utilized for irrigation water resources and has been recognized as World Cultural Heritage by UNESCO since 2012. Currently, however, the future sustainability of the system is a big concern. Some operational and maintenance aspects of *Subak* are alarming, namely: network deterioration; limited availability of maintenance facilities either from government or farmers. *Sedahan* and *Sedahan Agung* which are traditional government official who mentors and supervise *Subak* operations are no longer functioning. Despite this condition, the ritual tradition of *Subak* which is a core element to *Subak* operations is still carried out. The ritual traditions vary from one region to another. There are several challenges in regards to *Subak* conservation. First, reduction of the *Subak* area, consequently farmers have less area to work on, resulting in declining income. Second, it has to do with deterioration of quality and quantity of water resources. Third, from demographic point of view, the average age of farmers is above 40 years with a heavy financial burden. Lastly, there are no clear regulations to support *Subak* operations. This study suggests several steps in keeping the sustainability of *Subak*. These steps are re-functioning S*edahan* and *Sedahan Agung* as government officials; providing government support to reduce cost levied to farmers; facilitating collaborations between farmers and other stakeholders; promoting alternative commodities beyond rice which have a higher financial value; preventing and repairing damages of upstream areas; controlling pollution; forming a coordination board at a provincial, regency and river basin level; building the *Subak* information systems; providing supervising mechanism, and encouraging academics and students to participate in an effort to preserve *Subak.*

Keywords: Subak in Bali, World Cultural Heritage, conservation, challenges, strategic steps

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PROSPECTS AND OPPORTUNITIES OF NON-GOVERNMENTAL ORGANIZATIONS IN UKRAINIAN IRRIGATED AGRICULTURE

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ABSTRACT

The article deals with the problem of modernization of irrigation management at the level of intra-economic network, as one of major factors of renovation of effective management of irrigated cropping in Ukraine. The main cause of low efficiency of irrigated agriculture in Ukraine is the producers' exclusion from the participation in irrigation water sharing and formation of pricing policy for water management services. At the same time, world experience shows that bureaucratic services, financed from the centre, lose their ability to effectively carry out irrigation service in a large number of small agricultural producers. This leads to the rapid infrastructure collapse, reduction of the irrigated area, improper sharing and losses of irrigation water, increasing soil flooding and salinization.

Modernization of irrigating systems management should begin with the creation of non-governmental organizations of water users. Management transfer process is rather lingering and requires legislatively supported political will and consolidation of the efforts of all stakeholders. In the initial phase, which should last no more than 2 years, it is necessary to transfer management of networks to newly-formed water users associations (WUA) or other NGOs. It is necessary to actively carry out stepwise, small-scale repairs and restoration works at the same time. All this is, mainly, at the expenses of international financial donors.

It is necessary for Ukraine to establish private ownerships and irrigated systems management at the level of intra-economic network. They will reduce the financial burden on budgets and attract investment by international donors.

Keywords: management transfer, rehabilitation, irrigation modernization, Water Users Association, Water Services Provider, consolidation, Ukraine.

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EQUITABLE WATER DISTRIBUTION IN CHIKOTRA RIVER COMMAND AREA (INDIA)

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ABSTRACT

The Chikotra river valley in Maharashtra, India comprises 52 villages. A pilot of water lifting and distribution was started with joint financing by government and farmers on 80:20 basis. Water distribution is based on copping pattern, decided by the Water Users Associations (WUAs). Federation of such WUAs is formed to manage the basin water as a link between the farmers and the Government.

The Chikotra River Project has eight Kolhapuri type weirs (KT Weirs) and 18 pickup Weirs. Water flows more than 150 days in the river. it is lifted by electric motor-pumps for irrigating during dry spells. The water from the weirs is lifted directly from the reservoirs up to the possible height. The land area with varieties of soil is suitable for growing high value crops, medicinal and forest products. The pilot area in the six villages is eligible to get irrigation water of 56,68,000 m^3 as per the norm fixed by the Federation of WUAs. Drip irrigation is obligatory for equitable water distribution.

The 1st phase of irrigation water distribution consists of allotting quota (in cubic metres) to each village on the basis of the village population. The 2nd and the 3rd phases cover the block (21 ha) and valve level (2 ha), depending on the land slope. Each block is assigned a certain quantum of water and the farmers are expected to use it efficiently. For the convenience of the farmers, the cropping pattern is designed by the Federation for each block. However, freedom is granted to the group of farmers under one valve to select any one crop within the limit of water use up to 18,400 m^3/ha (80,000 m^3 for 21 ha). Multiple crops are grown in the blocks

Keywords: Chikotra River, Equitable water distribution, WUAs, Irrigation, Cropping pattern.

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ROLE OF WATER USERS ASSOCIATION IN MANAGEMENT, OPERATION AND MAINTENANCE OF IRRIGATION SYSTEMS IN INDIA

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ABSTRACT

The management of natural resources like water requires voluntary participation by those who benefit from the productive use of this resource. Due to this reason, states have been trying to foster participation of farmers in the management of irrigation systems in India. After 1985, Government of Maharashtra has taken keen interest in the formation of water users' co-operative societies'. Management operation and maintenance of the distribution systems are done by the water users' co-operative societies themselves.

This paper is based on the study of the role of water users association (WUA) in management, operation and maintenance of Waghad Irrigation Project, Maharashtra State, India. This is unique case in which complete control of the irrigation projects is handed over to the federation formed by 24 farmers' WUAs. This federation is the apex organization called Waghad Project Level Water Users Association (WPLWUA). The study reveals that economic and equitable distribution of water have improved and crop productivity has increased significantly after handing over the irrigation scheme to the WPLWUA. Beneficiary farmers are taking double, multiple and varied crops according to their own preferences, otherwise in elsewhere cropping pattern is imposed by the projects authority. Water is distributed on volumetric basis rather than area basis from tail to head. Each and every water users associations are keeping their up-to-date records and publishing their annual reports every year. This project has got several state and national awards for efficient and participative management, operation and maintenance of irrigation systems in India.

Keywords: Participatory Irrigation Management, Waghad Irrigation Project, Water Users Co-operative Societies, Water Users Association.

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THE USE OF UNMANNED AERIAL SYSTEMS FOR OPERATION AND MAINTENANCE OF IRRIGATION SYSTEMS

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ABSTRACT

UAS, Unmanned Aerial Sistems, Remotely-Piloted Aerial Devices, or simply, drones are a tool of increasing use in engineering and a situations where a manned inspection is not possible. With the advent of low-cost equipment with sophisticated computer vision, robotics and geomatic engineering, these devices are able to generate high-resolution images and videos even with low cost cameras. Performance of irrigation infrastructure depends on its maintenance to maintain functionality, operability and to ensure life expectancy, which demand frequent supervision and use of resources. This report describes the potential use of UAS's to help monitor operations and maintenance activities of Mexican irrigation systems. The results indicate that UAS's provide the appropriate platforms for a remote sensor-based at reduced cost and labor, to expedite the supervision and monitoring process of hydraulic infrastructure, such as: opportune detection of water leaks, performance of irrigation service, and advances of maintenance jobs.

Keywords: UAV, dron, monitoring and supervision system, image processing, irrigation schemes.

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APPLICATION OF POLYETHYLENE FILM FOR CONTROL OF SOME SUBMERGED WEEDS IN IRRIGATION CANAL

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ABSTRACT

The objective of this project is to investigate the efficiency of polyethylene films used for aquatic weed control in an irrigation canal. The study areas are the Kampangsan Operation and Maintenance Project, Kanchanaburi province and the Songpeenong Operation and Maintenance Project, Supanburi province, Thailand. The project was conducted during October 2008 to September 2010. The study applies covered treatments to control pondweed (*Potamogetonmalaianus* Miq.), hydrilla (*Hydrillaverticillata* (Lin.f.) Royle), bushy pond weed (*Najasgraminea* Del.), and duck-lettuce (*Otteliaalismoides* (L.) Pers), which are noxious aquatic weeds in an irrigation canal. There are four treatments consisting of no cover, cover with black plastics polyethylene sheet, cover with black polyethylene woven sheet, and cover with 80% shading net. The results show that the treatments can decrease duck-lettuce by 100% at 14 days, and bushy pond weed and hydrillaby100% at 28 days. The pondweed was decreased by 100% with the 80% Shading Net at 28 days. There were no significant differences on aquatic weeds control between Black Plastics Polyethylene Sheet, Black Polyethylene Woven Sheet and 80% Shading Net. The aquatic weeds were absent from the irrigation canals used for the study for 6 months afterwards.

Key words: Polyethylene Film, Submerged Weeds, Irrigation Canal**.**

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ANAEROBIC WASTEWATER TREATMENT FOR A COMMUNITY LIVING NEAR AN IRRIGATION CANAL

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ABSTRACT

The project took place at Donsai Sub-District, Photharam District, Ratchaburi Province. The major pollution sources affecting irrigation water quality in the area were found to be the pigsties, the bean curd factories, and the community wastewater. Water treatment tanks were made for a pigsty and a bean curd factory in order to be a model for wastewater management in the area. The tanks were made from fiberglass. The prototype tanks for a pigsty, which produces manure with high organic matter, are two 22 m^3 tanks, while the prototype tanks for a bean curd factory are two 10 m^3 tanks. The tanks shape is capsule placing horizontally. There are legs supporting the weight and there is an opening at the top for cleaning-up purpose. The interior of the tanks was divided into compartments to let the wastewater circulate. The last compartment places a cylinder container of 2.5 cm diameter and 2.5 cm length for anaerobic microbes to treat and decompose organic matter in the wastewater. The results show that the treatment can effectively reduce BOD of water in the irrigation canal.

Keywords: Irrigation canal, Anaerobic water treatment, BOD.

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ENCOURAGING FLORICULTURE TO REDUCE POVERTY - SRI LANKAN EXPERIENCE

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ABSTRACT

Floriculture is a high income generating agribusiness and can open up great opportunities to especially women growers. Floriculture uses less water in poly tunnels and net houses. Income per unit area from floriculture is much higher than any other crops of agriculture. The potential of floriculture as an industry has not been exploited properly in Sri Lanka. Wide ranges of floricultural items are produced by the growers such as cut flowers, foliage plants, flowering plants, pot plants, climbers and grasses.

The national policy of the government of Sri Lanka supports establishing small scale businesses and build up links with growers and institutes. Accordingly, many supporting networks were developed by government and non-government organizations (NGOs) to provide training and infrastructure facilities to empower women in rural and suburban areas. But, no research has been done to evaluate effectiveness of these programs.

This study examines the effect of supportive networks on the income of women floricultural growers. Using both survey questionnaire and interviews, a random sample of hundred women floriculture growers located within Colombo and Gampaha Districts of Sri Lanka was utilized. The study indicated that the utilization of supportive networks and development of social capital enhanced the income of women floricultural growers and reduces poverty.

Keywords: Low water use, social capital, women empowerment, floriculture sector, Sri Lanka.

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PILOT SOLAR IRRIGATION APPLICATIONS IN SOUTHEASTERN ANATOLIA REGION: A MULTI-PARAMETER ANALYSIS BASED ON STATISTICAL DATA

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ABSTRACT

In the South-eastern Anatolia (GAP) Region of Turkey, large areas of agricultural land are opened up to irrigation through various projects. Among the major drawbacks of the GAP region is the complications in charging the utility bills, due to high power consumption in supplying water for irrigation. Hence, the need for resource-efficient technologies, including solar-driven irrigation systems, energy-efficient irrigation pumps, and water-efficient irrigation systems is very strong. Due to renewable energy legislation In Turkey, using irrigation pumps run by solar power is an alternative even at the locations served by the national grid. The saleability of excess energy to the national grid makes the system's usability viable out of the irrigation season.

Four micro-scale pilot projects in solar irrigation were realized within the "Utilization of Renewable Energy Resources and Increasing Energy Efficiency in Southeast Anatolia Region Project (REEE)", which is being implemented by GAP Regional Development Administration, in co-operation with the United Nations Development Programme (UNDP), in August 2013. The measurement devices at three pilot stations have been collecting data on the technical parameters, including generated power, flow rate of pumped water, and meteorological variables.

The collected data were used to study the effects of each independent variable, including solar irradiation density, module temperature, and ambient temperature on dependent variables, including water flow rate, accumulated energy in battery group, consumed power, and portion of output power transferred to national grid. The results will be employed in development of a tool, to design solar irrigation systems with optimum technical characteristics and best economic rates of return in their life-cycles, taking into account a set of parameters. The resource-saving opportunities will be communicated with government bodies to develop regional support structures and incentive mechanisms in employment of solar irrigation systems.

Keywords: Solar irrigation, Techno-economic assessment, Regional development, GAP Region.

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LEARNINGS FROM HERITAGE IRRIGATION STRUCTURES AND SYSTEMS IN CHINA

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ABSTRACT

During its long history, China has built numerous irrigation projects and systems that have laid foundation for the country's development of agriculture, population, society and culture. The seven projects listed as ICID's HIS from 2014 to 2015, including water storage irrigation structures, diversion irrigation structures with and without dams, terraces with irrigation engineering system and shad of irrigation system, are highly representative of the engineering level of irrigation in pre-modern China in terms of environment suitability, systemic and low impact planning, ingenious structure design, ecotypic material and irrigational management. The empirical knowledge and engineering philosophy reflected in these heritages, such as adaptation to local conditions and advancing with the times, and especially management mechanism giving consideration to both upstream/downstream and left/right bank area, thorough annual repairs systems, and division of responsibilities between and cooperation of government and private sector, can serve as a valuable reference for contemporary irrigation construction and development.

Keywords: Heritage irrigation structure, management, China, learning.

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HISTORY OF LARGE SCALE IRRIGATION AND DRAINAGE PROJECTS AND THE GROWTH OF REGIONAL SOCIETIES IN TAIWAN

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ABSTRACT

Taiwan has been facing double exposure on agriculture as developed countries in the Eastern Asia in these days. The performance of large-scale irrigation projects deeply affects the vulnerability and the adapting capacity for local food security. This paper demonstrates the development of irrigated agriculture in Taiwan, and focuses especially on the history of large scale irrigation and drainage projects, critical agricultural issues to which Taiwan has been facing, and challenging cases of cooperation between agricultural sector and industrial sector based on literature review and field survey. The coming global food crisis is not only a result from the increasing world population, but also from the climate change and economic growth. That means the vulnerability of agriculture should be examined, the adapting capacity to climate change will decline and the competition for water, labor and land resources between sectors will become keener due to the economic globalization. In the case of irrigated agriculture, sustainable development strategies must be taken up as well as environmental changes.

Keywords: Taiwan, Irrigation and Drainage, Water management, Agricultural development projects, Infrastructures.

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OPTIMIZING THE HYDROELECTRICITY AT MAE KLONG DIVERSION DAM, THAILAND

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ABSTRACT

Most of the reservoirs in Thailand are designed to meet the downstream water uses together with hydropower production serving for the increasing power needs in the future. In the past few decades, many hydropower development projects in Thailand have been planned and developed especially at large storage dams and some small and medium dams like Mae Klong Diversion Dam located in the western region. Mae Klong Hydrohypower Plant has been constructed in 2014 and operated by the joint co-operation between the Electricity Generating Authority of Thailand (EGAT) and the Royal irrigation Department (RID) for reservoir operation and water distribution through the canal irrigation system. Accounting for the energy production without interrupting agricultural water needs and environmental flow requirements on the downstream side of the dam, this study aimed at optimizing the hydroelectricity to find the optimal solution in term of reservoir operating rules at Mae Klong Diversion Dam. The simulation model for reservoir system operation was developed and optimization model was also formulated based on the consideration of power benefits. The results present the alternatives for the reservoir operating rule such as optimal daily release, linear release rule, simple rules, and their performances obtained from the developed model for facilitating the reservoir operators in decision making.

Keywords: Mae Klong Dam, Simulation-Optimization Model, Linear Release Rule, Hydropower.

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CANAL AUTOMATION FOR IRRIGATION SYSTEMS: AMERICAN SOCIETY OF CIVIL ENGIENERS MANUAL OF PRACTICE

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ABSTRACT

Recently, the Task Committee on Recent Advances in Canal Automation, which is part of the Irrigation Delivery and Drainage Systems Committee (IDDS) of the Irrigation and Drainage Council (IDC) of the Environmental and Water Resources Institute (EWRI) of the American Society of Civil Engineers (ASCE), prepared a Manual of Practice (MOP) on canal automation for irrigation systems. Formally referred to as MOP 131 *Canal Automation for Irrigation Systems*, this book focuses on the technical aspects of modernizing irrigation systems through the use of automated canal control systems. MOP 131 is an essential reference for professionals in agricultural and irrigation engineering, as well as owners, managers, and operators of irrigation water delivery systems.

The Task Committee was formed because although there has been continual research in the field of canal automation, there has not been a formal publication on the topic for some time. From the beginning, the Task Committee wanted the final product to be a truly international effort that would be useable in all countries. Indeed, the Task Committee itself was composed of researchers and engineers in multiple countries including the United States, the Netherlands, Australia, France, Spain, Portugal, China, and Mexico. In all, more than 40 different professionals from 8 different countries participated in the development of MOP 131.

This paper provides a brief summary of MOP 131 within the context of the history and future of canal automation.

Keywords: Canal Automation, Automatic Control, Feedback Control, Feedforward Control, SCADA Systems, Water Level Control, Flow Rate Control, Canal Infrastructure.

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STUDY ON CONJUNCTIVE USE OF GROUNDWATER AND SURFACE WATER FOR PADDY RICE IRRIGATION IN SANJIANG PLAIN NORTHEAST CHINA

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ABSTRACT

Most of the paddy rice in Sanjiang Plain is irrigated with groundwater. In recent years water requirement is increasing with the rapid increase of paddy field while groundwater table is falling continually. In order to maintain sustainable development of water resources in the region in the long term, comprehensive measures, including conjunctive use of surface and groundwater and water saving practices should be jointly applied. To investigate these comprehensive measures a study on conjunctive use of groundwater and surface water for paddy rice irrigation in the region has been implemented since 2014. This paper presents the water management scenarios for the region based on the study by adopting various water-saving irrigation technologies and measures, volume of reused water, and application of groundwater and surface water. A semi-distributed water balance model was developed to simulate water cycle at irrigation district level factors so as to analyse water use efficiency and dynamic groundwater response to various scenarios. Based on this study, reasonable water use modes under different hydrological years are proposed. These modes show how and when to use groundwater, surface water and return flow. The outcome of the study can also be used to provide theory basis for the optimal allocation of regional water resources.

Keywords: Groundwater, surface water, water reuse, water use efficiency, paddy irrigation.

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PERFORMANCE EVALUATION OF IRRIGATION SCHEMES TO IMPROVE LAND & WATER PRODUCTIVITY: A CASE STUDY OF RAJANGANA IRRIGATION SCHEME IN SRI LANKA

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ABSTRACT

The Present study of Rajangana major irrigation scheme using a 12 year dataset captured a holistic picture of seasonal irrigation productivity on a water management unit basis with 11 indicators covering Service Delivery, Agriculture Production, Agriculture Economics and Financing. Water use efficiency measured by "System Water Delivery Service" and "Irrigation Duty" were 1.13 and 1.992 m/ha, respectively. "Total MOM cost/unit area" and "Maintenance Budget Implementation Efficiency" measuring the average efficiency of performance level in operation and maintenance were 60.11% and 94.02%. Average agriculture productivity was 4.073 Mt/ha, having average efficiency of performance at 91.53%. "Cropping Intensity" measuring the land productivity reflected full performance with an average value of 2.01. Average water productivity of 0.102kg/m3was far below the benchmark of 0.372kg/m3. Average efficiency of the performance in "Resource Utilization" and "Profit" were 47% and 61.36%. System sustenance levels focusing on irrigation infrastructure maintenance with twonew indicators namely "Beneficiary Involvement" and "Government Involvement" showed that over the study period, annual contribution to system sustenance declined at a rate of 3.06% and 6.0%respectively,with average efficiency in performance of 49.81% and 68.78% indicating system deterioration.

Keywords: Water, food, climate, performance, intervention, productivity.

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UTILIZATION OF WATER RESOURCES OF MEKONG RIVER IN LAO PDR UNDER ADVERSE TOPOGRAPHICAL AND SOCIO-ECONOMIC CONDITIONS

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ABSTRACT

Lao People's Democratic Republic (Lao PDR) is largely mountainous, with mean elevation 500 m amsl. About 85% of the country's territory is part of the Mekong River Basin, whose water resources are key to the development of the country's agriculture.

Some of the target areas of the Government of Lao PDR for accelerated development of irrigated agriculture are the fertile lands in the Champassack province. Development of irrigation has been severely constrained due to adverse topography where only lift irrigation is possible from Mekong river. But this requires large scale installation of pumpsets and allied irrigation infrastructure. Major constraint was the lack of financial resources of the Government for capital works and general lack of equipment and trained man power for operation and maintenance of the existing irrigation infrastructure.

For the rehabilitation of the Champassack Irrigation Project comprising six irrigation schemes in the Province, WAPCOS Ltd., of India was appointed Project Developer by the Government of Lao PDR. The Project had the following four components:

(i) Completion of six irrigation schemes (5462 ha)
(ii) Installation of ten existing large pump sets
(iii) Conversion of existing diesel driven pump sets to electric driven pump sets
(iv) Improving 3 pump service centres at Vientiane, Savannakhet and Pakse.

These schemes have enabled the farmers to grow two rice crops and some cash crops in a year which has improved their socio-economic condition through sustainable food production.

Keywords: Lift irrigation, Rice cultivation, Livestock raising, Irrigation infrastructure, Command area.

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SEDIMENT FLUSHING STRATEGY FOR RESERVOIR OF PROPOSED BHASHA DAM, PAKISTAN

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ABSTRACT

Reservoir sedimentation is a major problem world wide. Large reservoirs in Pakistan have lost 33% of their design capacities due to sedimentation. Diamer Bhasha Dam having storage capacity of 10 BCM is proposed in northern areas of Pakistan on Indus River having average annual sediment inflow of 196.91 million tons/year at dam site. Evaluation of sediment management measures is necessary before the start of such mega project. Various methods are in use to maintain storages of reservoir but sediment flushing has been opted in this study as compared because of economy and prevailing site conditions. The HEC-6KC model, an extended version of the original HEC-6 model, has been used for sediment simulation and flushing.The life of the reservoir without any sediment management measure is estimated 70 years, with annual capacity reduction of 1.16%. Different flushing scenarios have been evaluated and it is found that the life of reservoir could be extended to more that 140 years through sediment flushing. The sediment balancing ratio (SBR) nearly equal to 1 and long term capacity ratio (LTCR) of nearly 0.5 can be achieved through annual sediment flushing at drawdown level below 1010m amsl with the reservoir release above 5,300 m^3/s for 30 days.

Keywords: Sedimentation, Diamer Bhasha Dam, Sediment Flushing, Indus River Pakistan, Sediment Balancing Ratio, Long Term Capacity Ratio.

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BALANCE ANALYSIS OF NITROGEN AND PHOSPHORUS FOR THE FERTILIZATION MANAGEMENT OF RICE PRODUCTION IN SOUTH CHINA

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ABSTRACT

In this paper, typical paddy fields located in three rice-based cropping systems, namely Guilin in Guangxi Province and Jingmen and Xiaochang in Hubei Province, were selected to investigate the inputs and outputs of nitrogen (N) and phosphorus (P). The main results can be summarized as follows. (1) Chemical fertilizers were the dominant source of N in all three study sites. The average N application rates were 287.50 kg/hm^2 in Guilin (double rice), 130.55 kg/hm^2 in Jingmen (single rice) and 172.41 kg/hm^2 in Xiaochang (single rice). These inputs accounted for 83.43%, 71.64% and 76.91% of the total N input, respectively. Correspondingly, fertilizers, along with soil were the dominant sources of P that together accounted for over 99% of the total input. (2) Uptake by the rice plants and drainage losses of N were different in the three sites, because of different fertilization and irrigation practices – Jingmen had the highest uptake efficiency and lowest losses through drainage. Overall, all three sites had low N utilization efficiency (28.16%–39.73%) and considerable losses through drainage (23.29%–39.53%). The efficiency of P uptake in all three sites (40.93%–61.76%) was higher than that of N, due to the lower drainage losses (0.33%–4.26%); however, the losses through plants retention in drainage ditches and leaching were relatively high (34.52%–58.73%). (3) An independent t-test showed that the total N content of soil in the paddy fields did not change significantly due to transplanting and harvesting both in Guilin and Jingmen, while in Xiaochang there was a surplus of N (53.93 kg/hm^2). The quantity of available N in all three sites was reduced by different amounts (11.58–22.76 kg/hm^2), indicating that measures to promote N recovery efficiency and soil N mineralization were needed instead of increasing N application rate. The total and available amount of P in the soil were reduced significantly in the three sites, particularly in Guilin due to the low rate of P application on single crops (18.91 kg/hm^2), where the reductions were 87.51 kg/hm^2 and 24.30 kg/hm^2, respectively. In order to achieve balanced fertilization, N application rates of approximately 120–130 kg/hm^2 on single crops and 280 kg/hm^2 on double crops were recommended, as were P application rates of approximately 90 kg/hm^2 on single crops and 120 kg/hm^2 on double crops. The current study of N and P mass balances and dynamic changes of nutrition in paddy fields in South China provides references for establishing rational fertilization and irrigation practices.

Keywords: Paddy fields, Nutrient management, Application rate, Nitrogen, Phosphorus, China.

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IMPROVED ON-FARM WATER MANAGEMENT PRACTICES FOR MAJOR CROPS IN PAKISTAN

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ABSTRACT

Traditional irrigation practices, low crop productivity, unlevelled fields, water losses taking place during conveyance and application phases and low irrigation efficiencies are the main problems ofthe common farmers in Pakistan. To overcome these problems, different on farm water management technologies such as precision land levelling (PLL), bed planting, drip irrigation system and watercourse improvement were provided to farmers for water savings and increasing crop yield in the area of rice-wheat zone (Khurrianwala distributary), cotton-wheat zone (Mungi distributary) and mixed cropping zone (Killianwala distributary) during cropping seasons of 2006 to 2015 under JICA funded project of On-farm Research and Development Component in LCCS (East), Rachna Doab, Punjab, Pakistan.

On the average, there was 25% water savings and 15-20% increase in crop yields on 2024 hectares (5000 acre) fields under PLL. Wheat, cotton and rice on PLL fields produced more yields (kg/ha) than those on conventional fields i.e. (3727 vs 3105), (3371 vs 2856) and (4242 vs 3688), respectively. All fields under PLL were brought under bed planting, which saved 50% water and increased the crop yield by 15-25%. Wheat yields under bed planting (4770.1 kg/ha) was 20 % more than that under conventional method of flat sowing (3726.9 kg/ha). Cotton yields was 15 % more under bed planting (3778.5 vs 3285.6 kg/ha) than those under conventional fields. The grain yields of rice on beds was significantly higher (5302 vs 4241.8 kg/ha) than that under flat sowing. These results indicate that wheat, cotton and rice sown on beds saved 42.6%, 38.6% and 31.4% of irrigation water, respectively, compared with flat sowing. Drip irrigation system was installed on 4.86 hectares (12 acres) at the above mentioned distributaries. The use of drip irrigation resulted in savings of not only water but also fertilizer and increased the crop yields by 30 to 40%. Three watercourses, one on each site of 1200 m in length, were lined which resulted in improved conveyance efficiency of 15-20%. These results envisage showing potential of on-farm water management technologies for saving water as well as increasing crop yields.

Keywords: PLL, bed planting, wheat, cotton and rice, irrigation water saving.

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EFFICIENT IRRIGATION BY APPLYING A WATER BALANCE: A SOUTH AFRICAN EXPERIENCE

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ABSTRACT

Irrigated farming can succeed efficient irrigation in well-drained soils by understanding and applying the water balance approach. International Commission on Irrigation and Drainage (ICID) has approved the newly developed water balance framework for irrigation efficiency. Adapting this, South Africa has developed a South African framework for improved water use efficiency. The framework was applied to re-assess the system efficiency indicators typically used by irrigation designers when making provision for losses in a system and converting net to gross irrigation requirements. A new set of system efficiency values for design purposes was therefore developed.

The water balance approach can be applied at any level, within defined boundaries, or across all levels to assess performance within the whole Water Management Area. Studies and research over 40 years in South Africa on the techniques of flood-, mobile- and micro-irrigation contributed to the knowledge base of applying irrigation methods correctly. The fraction of the water abstracted from the source that can be utilised by the plant, can be called the beneficial water use component and optimised irrigation water supply is therefore aimed at maximising this component.

In South Africa an area of 16 000 000 ha is cultivated and 1 600 000 ha are being irrigated. Poor drainage problems in South Africa are reported to have reduced the crop production potential of about a quarter of the total land under irrigation.

With effective water management and good subsurface drainage, improved soil health conditions are now created for successful irrigation farming to assist with food security. The resulting approach of “measure; assess; improve; evaluate”, promotes an investigative water balance approach to improve water use efficiency.

Keywords: Irrigation, Water balance, Water management, irrigation Efficiency.

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DESIGN IRRIGATION, MANAGEMENT AND EXTENSION PRACTICES IN BLUE BERRIES (Vaccinium corymbosum L.) TO IMPROVE "INSIDE-GATE WATER FOOTPRINT": A CASE STUDY IN CONCORDIA, ARGENTINA

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ABSTRACT

Proper design, management and extensive practices to irrigation workers, are tools to improve water use efficiency, relevant agent to give solutions to the increasing demand of food, sustainability and productivity of irrigated crops. All the water used in the farm, including the water used in packing facilities to clean tools and machinery, fresh water used and all other uses inside gate, must be well managed, to reach an efficient use of water resources, and to reduce the use of water measured as "inside- gate water footprint". The aim is to present the result of the design, management and proper operation of an irrigation system in blueberries (Vaccinium corymbosum L.) in Argentina, measuring the water footprint to evaluate water productivity, hand labor used per ha and net income reached per water used. Water volume used per unit of net income for farmers is a good indicator to decide in the crop in which water will be destined. The optimal design and managing of irrigation systems at farm level is a key factor for a rational use of water, economic development of the agriculture and its environmental sustainability.

Keywords: Irrigation design, Water management, Water footprint, inside gate water footprint, blueberries.

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AGRICULTURAL PRODUCERS COMPANY : A WAY FORWARD FOR SUSTAINABLE PARTICIPATORY IRRIGATION MANAGEMENT

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ABSTRACT

Management, operation and maintenance (MOM) of the irrigation systems is a dynamic, multifarious activity wherein roles of water users, private sector, government organizations and civil society hold important bearing on its sustainability. Maharashtra has been pioneer in involving water users and civil societies in irrigation management with adequate policy and technical support from the government. Irrigation management of Waghad medium Irrigation Project in Nashik district, catering benefits to 9621 Ha, is carried out by project level association of WUAs (PLWUA) from last 10 years. Waghad is a successful example of long term partnership among water users, civil society and government organisation. Waghad success story has inspired many WUAs of other irrigation schemes to take over irrigation management.

Waghad example has developed a confidence among farmers that they can do MOM of irrigation system, effectively.As a step forward and as an effort to improve the net income of farmers, PLWUA has formed an innovative “Waghad Agricultural Producers Company (WAPCO)” to provide agricultural inputs at competitive prices and to market agricultural produce so as to reap the benefits of bulk purchases.The Company has been endeavoring to develop linkages with private sector to collectively bargain for the benefit of farmers. Waghad farmers’ innovative way to form Producers Company has encouraged many farmers and WUAs to come forward to go beyond water management. Dev Nadi and Green valley Agricultural Producers Company, Sinner are few examples of it. It has been demonstrated by these case studies that if farmers are united for carrying out MOM of irrigation systems and venture in agricultural marketing through producers companies, it would provide financial strength to WUAs and eventually improve net income of member farmers.

In the present paper a case study of an innovative management by WUAs in Waghad system is presented. It is hoped that the study could be an example to follow by other WUAs in the country and elsewhere.

Keywords: Water Users Associations , Agricultural Producers Company, Sustainable.

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FEASIBILITY STUDY OF DOMESTIC WATER SUPPLY USING AGRICULTURAL RESERVOIRS IN RURAL AREA OF KOREA

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ABSTRACT

Supplementary domestic water supply potential of agricultural reservoirs managed by Korean rural community corporation (KRC) were investigated. Water quality of 136 reservoirs met the criteria of domestic water source with less than 3 ppm COD. Water balance analysis was conducted for ten year frequency of drought on the reservoir water. Results showed that 116 reservoirs were eligible for domestic water supply while satisfying irrigation water supply even in drought period. Economic analysis was also conducted using NPV method, B/C method, Internal Rate of Return, Profitability Index method. Results showed that several reservoirs would satisfy economic feasibility if water was provided from reservoir outlet instead of delivering water to treatment plant under current conditions. Saving irrigationa while increasing irrigation efficiency is recommended to acquire domestic water in rural area.

Keywords: Agricultural reservoirs, rural community, domestic water, economic analysis, feasibility.

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A BROWSER / SERVER FRAMEWORK FOR CROP ET CONTROL AND IRRIGATION MANAGEMENT IMPROVEMENT USING REMOTE SENSING DATA

Lei Wang[1], Yu Liu[2], and Zhigong Peng[3]

ABSTRACT

Agriculture accounts for 70% of the total water consumption in North China. With socioeconomic development, the consumption of industry and domestic supply is increasing sharply. The shortage of irrigation water is a critical problem affecting agriculture production and food security. The research focuses to water demand management rather than water supply management to meet the constraint of regional water resources. A crop ET management tool based on Browser/Server structure and GIS technique was developed to assess irrigation management options and improve water use efficiency at regional scale. The frame work extracted cultivated land ET control target from regional ET control target and then analyzed present water consumption distribution based on remote sensing and field observation data. Crop ET management tool is the kernel of the framework which provided four main function modules including crop ET quota control, crop pattern improvement, water saving potential calculation and irrigation quota estimation. A regional crop ET quota was proposed by comparing crop water requirement and economical ET. High water consumption crops were reduced according to cultivated land ET control target. The regional water-saving potential in irrigation was determined by selecting a regional crop ET quota as an upper limit. The framework was flexibly applied in four counties and irrigation districts in arid or semi-arid area in North China.The new calculation method for water-saving potential for crops will help planners and managers gaining a better insight into water management and water uses of crops, which will in turn provide information and guidelines needed for regional water plans, water rights allocation and agricultural water applications.

Keywords: ET management, Crop ET quota, Rremote sensing data, Iirrigation quota, Irrigation schemes, Water saving potential.

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IMPROVING SURFACE IRRIGATION IN MEXICO AS NATIONAL POLICY PRIORITY

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ABSTRACT

Mexico's population will increase 30% by 2050 demanding a sharp increase in food mainly from irrigated agriculture. However, agriculture demands water, an increasingly scarce, variable and shared resource in a context of population growth, economic development, climate change and environmental awareness. Irrigated agriculture has adapted to natural rainfall variability with large investment in hydraulic infrastructure and conversion from surface irrigation to pressurized irrigation system. However, surface irrigation systems are still dominant in Mexico covering more than 90% of irrigated land. Consequently, the Mexican government implemented an integral program to improve surface irrigation called Technified Surface Irrigation Project (RIGRAT for its acronym in Spanish) in large-scale irrigation districts. This paper describes the RIGRAT program as adopted in a changing world, operated by trained field technicians as Water User Associations (WUAs) staff and supervised by the federal water agency with the following components: scientific irrigation scheduling, surface irrigation design, irrigation application, volumetric delivery, and irrigation evaluation and irrigation service follow-up. After two water years of implementing the program, the results indicate that it is possible to reduce field irrigation depths without decreasing conventional yields, improving irrigation practices with participation from irrigation extension workers, farmers, WUAs, federal government and universities under the umbrella of an integral program to improve surface irrigation as a WUA service.

Keywords: Furrow irrigation, Irrigation service, Irrigation policy, Mexico.

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WATER MANAGEMENT FOR INCREASING FEED RICE YIELD AND FOR ENVIROMENTAL CONSERVATION: AN EXPERIMENTAL STUDY

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ABSTRACT

Feed rice was planted in 80,000 ha of paddy fields in Japan in 2015. Feed rice production is predicted to increase because the Japanese government has recommended the cultivation of feed rice for securing food safety and increasing the food self-sufficiency ratio. In general, because feed rice farmers place importance on rice yield and not rice taste and quality, it is possible to increase irrigation and fertilizer more than for rice cultivated for human consumption. In this study, we first determined water balance and runoff load (nitrogen and phosphorus, chemical oxygen demand [COD]) for paddy fields with feed rice (Oryza sativa L) cultivation in Goshogawara City in the northern part of Japan from May to October 2015. The amount of water and the quality of the water were analyzed from irrigation canals, drainage pipes, the surface of paddy fields, and rainfall each day. Secondly, we conducted cultivation studies under conditions of flooding and intermittent irrigation. As the results, the paddy fields of feed rice were of the drainage type, in which much outflow was drained from the drainage. Water balance for the irrigation period was as follows: total irrigation was 2,513 mm, total rainfall was 273 mm, total drainage was 1,672 mm, total evapotranspiration was 620 mm, and total percolation was 552 mm. The runoff load for the irrigation period was high as follows: T-N was 42.1 (kg ha^{-1}); T-P was 12.8 (kg ha^{-1}); COD was 326.9 (kg ha^{-1}). Concerning pot cultivation studies, differences in irrigation management affected yield. The average yields of flooding treatments (1112 kg per 10a) were higher than that of intermittent treatments (732 kg per 10a). The total runoff load of T-N in flooding treatment was 9.3 (Kg ha^{-1}), in intermittent irrigation treatment was 29 (Kg ha^{-1}). In terms of environmental conservation and yields, it is thought that flooding is a beneficial method of water management.

Keywords: Feed rice, water balance, Runoff Load, Water Management, Flooding, environmental conservation.

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ASSESSMENT OF NITROGEN DEMAND OF CROPPING PATTERN BY CRITICAL PLANT NITROGEN CONCENTRATION INDEX (CASE STUDY: VARAMIN IRRIGATION AND DRAINAGE NETWORK)

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ABSTRACT

Nitrogen is an important factor for biomass production. In cropping systems, nitrogen fertilization can provide adequate N supply for plants to achieve the potential yield. However, to ensure reaching to this potential yield, farmers often apply more than the required N fertilizers. Nitrogen overuse increases the risk of its leaching to groundwater, contaminating groundwater and threatening the human health. In recent years, critical plant nitrogen concentration equation is used to determine crop nitrogen demand during the different growth stages of plants. The purpose of this study is to determine the nitrogen demand of Varamin network's cropping pattern by using the critical plant nitrogen concentration equation and comparing the result with the amount of nitrogen fertilizer commonly applied in the study area. In this study, monthly biomass production for growing period was determined based on normalized water productivity index and plant canopy development. Coefficient of critical nitrogen concentration equation for each plant was determined by previous researches. The result of this study showed that for barley, the amount of nitrogen applied in Varamin network is equal to nitrogen demand of the crops and for wheat, maize and tomato are 25%, 61% and 18%, respectively, higher than the amount obtained from critical plant nitrogen concentration equation.

Keywords: Crop nitrogen demand, Nitrogen fertilizer, Cropping pattern, Varamin network, Iran.

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VALUE EVALUATION OF THE IRRIGATION INFORMATION SERVICE SYSTEM FOR RICE CULTIVATING FARMERS IN JAPAN

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ABSTRACT

In Japan, rice production currently faces problems shortage of successors and high labor costs. The Japanese central government is taking measures to promote the increase of the management scale of the selected pillar farmers by entrusting farm land to them. Under the future provision of further expansion of the cultivation area per farmer, labor productivity should be enhanced by streamlining water management activities in rice cultivation. In this study, the study areas were selected in Aichi-yosui land improvement districts (LID) command areas in central Japan and Imbanuma LID command areas in eastern Japan. Firstly, practical service needs in regard to water management by the farmers were investigated by precise field observation of water management and interviews. Secondly, based on the needs, a novel "irrigation information service system (IISS)" utilizing ICT was proposed. IISS would enable farmers to check the floodwater depth and the picture of their plots through various information terminals such as smartphones and tablet terminals. Thirdly, IISS was installed in 5 trial plots to demonstrate its functions and performances to the potential users. It was revealed that the farmers felt frequent visits to their fields and the operation of inlet valves as the main burden. Some of the farmers were passive towards IISS, because of their unfamiliarity with ICT devices, great confidence in their conventional methods, and reluctance to additional investment. On the other hand, 79% were positive in their attitude towards IISS. It was also revealed that the potential users were going to pay 1,107 Japanese Yen per 1,000 m^2 field areas per year on an average. As the current water fees at the study areas are 5,430 Yen and 7,950 Yen per 1,000m^2 field areas per year respectively, it was understood that IISS has possibility to prevail if its cost would be within 20% of the current water fee. The analysis of the cost structure of IISS showed that the cost down of the water depth sensor has the highest priority and that the participation ratio is also an important factor to reduce the total cost. It was suggested by the interviews that agricultural corporations or farmers cultivating large areas might have needs for IISS to reduce labor for water management.

Keywords: Paddy field, Irrigation information service, ICT, Labor productivity, Plot water management.

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UNDERSTANDING COHESIVE SEDIMENTS BEHAVIOUR IN IRRIGATION CANALS USING DELFT 3D MODEL SIMULATION

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ABSTRACT

Irrigation system performance is affected by sediment deposition. Many researchers have studied non-cohesive sedimentation in rivers, coastal, estuaries and irrigation canals. While for cohesive sediments, researchers considered only rivers and costal, estuaries but not irrigation canals. This study simulates cohesive sediment in irrigation canals in order to understand their behaviour. The Delft3D model, which is originally used for rivers, was applied to a hypothetical case study main canal feeds one branch canal, to simulate the behaviour of cohesive sediments and water. In the first scenario, model calibration was done by assuming no sediments enter the main canal and comparing its results with those obtained from Duflow model. The results were close to each other and the flow was steady in the canal. In this way the model was calibrated and Delft3D can be used to simulate cohesive sediments in irrigation canals. In the second scenario, sediments entered the system and delft3D was used to simulate this scenario for three months. Because of the small size of cohesive sediment it was carried and transported through the main canal to the end and to the branch canal. Because of erosion and deposition, water levels are disturbed. Morphological changes in canals bed are seen in the branch canal where increasing velocity caused erosion to the canal bottom, while reducing velocity caused deposition. Based on the results of the calibration scenario, Delft3D can be used for irrigation systems. More studies needed to be done on cohesive sedimentation in irrigation canals especially for big irrigation systems.

Keywords: Sediment deposition, Delft 3D model, Calibration, Cohesive sediments behaviour.

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A COMPARISON ON SOIL PROPERTIES BETWEEN ORGANIC AND INORGANIC PADDY FARMING IN AWLEGAMA, KURUNEGALA, SRI LANKA

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ABSTRACT

A study was conducted to elucidate the soil differences in organic (OF) and inorganic farming (IF) field plots. The plot under OF was maintained with the application of rice husk charcoal, rice straw, green manure and *Azadirachta indica* (neem) seed extract. The IF plot was maintained with the application of chemical fertilizers, herbicides and pesticides. Soil samples were collected from randomly selected five locations in both field plots. Ammonium-nitrogen (NH_4^+-N), phosphate (PO_4^{3-}), pH and salinity were measured as chemical properties and soil organic matter (SOM) and bulk density (ρ_b) were measured as physical properties in both plots throughout the cultivation season.

NH_4^+-N fluctuated with three peaks in OF while it was single peak in IF coinciding the fertilizer application and in IF system has a distinct single peak occurring at later stage of vegetative phase., The concentration of PO_4^{3-} in OF system was increased after tillering stage and become fairly constant at around 26.7±0.4 mg/kg at the latter growth stage. In contrast, PO_4^{3-} content decreased continuously (from 29.3±9.1 to 21.2±4.7 mg/kg) towards the latter stage of plant growth. Soil responds only when the fertilizer was applied. However, addition of organic matter and its decomposition make the soil as nutrients pool.

Soil pH in the early crop growth stages were significant ($p<0.01$) among sampling dates in both farming systems. Soil salinity in OF was decreased towards the later part of its growth while in IF it was increased towards the latter stage of plant growth, but it was not significant ($p>0.05$) for both treatments. Application of rice straw leads to reduction of soil salinity in OF while in IF the application of synthetic agrochemicals leads to continuous increasing of salinity towards the latter stage. SOM in OF system was significantly ($p<0.05$) increased towards the latter stage up to two fold of their initial SOM content. In IF system SOM content was significantly ($p<0.05$) decreased towards the latter stage. The bulk density in OF system was significantly ($p<0.05$) decreased towards the later stage of the growth compared to IF system. It is concluded that the application of various inputs to paddy farming field leads to enhance the soil physico-chemical characters. Therefore proper management of farming inputs is important for the better soil productivity.

Keywords: Inorganic farming, IF, Organic farming, OF, Paddy cultivation, Soil properties.

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PREDICTION OF ENVIRONMENTAL FLOW CONDITION FROM RAINFALL USING RELATIONSHIP BETWEEN TENNANT METHOD AND STANDARDIZED PRECIPITATION INDEX

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ABSTRACT

In the present study, an effort has been made to describe the environmental flow condition of a watershed using Standardized Precipitation Index (SPI), a drought index based on the precipitation. Mohegaon, Manot, Hridaynagar and Sher are the four watersheds of upper Narmada Basin have been taken for the analysis. The purpose of this study is to derive relationship between environmental flow condition and the corresponding estimates of Standardized Precipitation Index which is used as measure of drought conditions. It is expected that these relationship will be useful in determining environmental flow conditions in ungauged sub-basins using rainfall data only. The study revealed an excellent relationship between SPI and percentage of average annual flow as the value of coefficient of determination are greater than 0.75. The analysis indicates that for each of the four watersheds the percentage of average annual flow increases with the increase in the value of SPI. It can be concluded that the relationships presented in this paper will be useful for estimating the EF condition for ungauged watersheds.

Keywords: Tennant method, Narmada basin, SPI, Environmental flow.

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STUDY OF TREFLAN MANAGEMENT ON GRAPEVINE ROOT CLOGGING IN SUBSURFACE DRIP IRRIGATION

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ABSTRACT

Subsurface drip irrigation (SDI) systems is highly efficient under water shortage condition, because water is directly applied to the root zone avoiding losses due to evaporation or runoff. To address the root clogging problem in SDI, a series of field experiments were conducted in the growing seasons of 2012–2013. The goal was to investigate the effects of Treflan injection on dripper clogging by roots, and on root distribution, yield, and the quality of grape (Keshmeshi Seyfried cultivar) under SDI. The research treatments comprised: (i) treflan injection treatment in concentrations of 25, 50, 100, 200 mg for each injections event, (ii) number of injections events: 1 to 3, (iii) root guard pipe and control (without terflan injection). Experimental design was randomized block experimental design in 3 replications. All of laterals were installed 40 cm below the soil. All plots received the same amounts of water and fertilizer. Irrigation event was 3-5 days and irrigation water was applied to increase the soil moisture content at root depth up to field capacity. The amount of irrigation was controlled using a flow meter installed on each laterals. At fruit ripening stage, different traits as weight, length and width of bunch and the qualitative traits including TSS, TA, pH and the volume of the juice were recorded. After harvesting, the root length density (RLD) and dripper discharge were measured. Some of drippers from each treatment were randomly chosen to observe evidence of root intrusion. Results indicated that treatments had no significant impact on juice volume, berry weight, bunch length, width, weight, annual vegetative growth and yield. In 2012 no root clogging was recorded but in 2013 root residues were observed in control treatment (without Treflan injection). In 2013 the discharge of drippers significantly decreased by 13.8% in comparison with first year. The two years experimental results showed that Treflan injection reduced root density effectively in areas adjacent to drippers. Accordingly, the potential of root clogging decreased significantly. Treflan concentrations of 25 and 50 mg had significant effects on decreasing grape root distribution by 9.7% and 19.2% compared with control. Because of yearly tendency penetration of root into drippers, it is recommended using of 25 and 50 mg respectively at first and second years of SDI systems utilization and increasing treflan concentrations gradually at next year's operation.

Keywords: Subsurface drip irrigation, Root clogging, Grapevine, Treflan.

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USING SWAT MODEL TO ASSESS THE IMPACT OF INCREASING IRRIGATION EFFICIENCY ON BASIN EFFICIENCY [Case Study: Abharrud River Catchment]

Fereshteh Batoukhteh[1], Hossain Dehghanisanij[2], and Farhad Misaghi[3]

ABSTRACT

The arid and semi-arid Iran has a fragile environment. The use of modern irrigation methods is one of the options to achieve optimal performance of irrigated agriculture by ensuring better water distribution uniformity, higher water use efficiency, and less water loss due to the evaporation, infiltration and surface runoff. On a basin scale, it is assumed that water loss from surface runoff and deeper infiltration may return to groundwater or river and can be considered as return flow. This scale was evaluated by SWAT methods. Then, amount of water returned and the basin efficiency was discussed in two scenarios: current situation and increase in irrigation efficiency by presurized irrigation systems

The study revealed that return flow was most important factor in water balance in a basin scale and 40 percent of the surface irrigation water is withheld in the basin. Under control scenario, the average efficiency of farm and basin was calculated, respectively, as 42 and 73 percent. Increase in irrigation efficiency by reduction in return flow, efficiency at basin scale did not change significantly. Basin efficiency was about 73 percent for both the irrigation methods namely, surface irrigation, and pressurized irrigation. Accordingly, to achive higher water productivity we must concentrate on technologies which reduce water evaporation.

Keywords: Irrigationefficiency**,** basin efficiency, Return water, SWAT model.

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EFFECTS OF DIFFERENT IRRIGATION METHODS AND MULCH ON CORN (*ZEA MAYZ L*) EVAPOTRANSPIRATION, YIELD, AND WATER USE EFFICIENCY IN A SEMI-ARID CLIMATE

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ABSTRACT

This study evaluated the Effects of different irrigation methods and mulching on field corn (Zea mays L.) actual evapotranspiration (ET_c), yield, water use efficiencies (WUE = yield/ETc, and IWUE = yield/irrigation) in Karaj of Iran. The experiment was laid out in a split plot design keeping three irrigations methods (i) porous clay capsules irrigation (CC), (ii) surface drip irrigation (SD) and (iii) subsurface drip irrigation(SDI) as the main factor and two kind of mulch (i) with and (ii) without Aluminium foil mulch as sub-factor. Each treatment was replicated three times in a randomized complete block design. Actual evapotranspiration (ET_c) was calculated by water balance method. Coefficients values for k_c, were derived from measured ET_c and ET_o calculated from weather data. Results showed that ET_c of corn for Karaj was 380, 377 and 372 mm for porous clay capsules, surface and subsurface drip irrigation, respectively. However for the same period, ET_c was estimated 374.22 mm using FAO Penman–Monteith model. Statistical analysis of evapotranspiration data indicated that the effects of irrigation methods were significant on evapotranspiration of corn ($P \leq 0.01$).The results showed that the K_c of porous clay capsules irrigation method in initial, crop development and middle stages of the growing season were 0.52, 0.78 and 1.19 respectively. The highest value of $K_{c\ was}$ for porous clay capsules irrigation method. The effect of irrigation methods on biological yield, WUE and IWUE were significant ($P<0.05$). The highest yield (30 ton ha^{-1}), WUE (7.89 kg m^{-3}) and IWUE (7.89 kg m^{-3}) was obtained for porous clay capsules irrigation method. The effect of mulch were significant on biological yield ($P \leq 0.05$), WUE ($P<0.05$) and IWUE ($P \leq 0.05$). But interaction of irrigation methods and mulch had no significant effect on biological yield, WUE and IWUE. Dry and wet biological yield increased from 25 to 28 (ton ha^{-1}) and 63 to 97 (ton ha^{-1}) for irrigation treatments respectively, and from 25 to 28 (ton ha^{-1}) and 73 to 84 (ton ha^{-1}) for mulching treatments, respectively. Mulch increased the biological yield, WUE and IWUE compared with the no mulch treatment. According to the results of this study, it can be concluded that using buried porous clay capsules leads to higher biological yield, WUE and IWUE compared to surface and subsurface drip irrigation. Accordingly it is a useful technique for maximizing water use efficiency in growing corn plant in semi-arid regions.

Keywords: Clay capsules irrigation, Surface and subsurface drip irrigation, Evapotranspiration, Biological Yield, Mulch.

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THE FEASIBILITY ANALYSIS OF DRIP IRRIGATION USING THREE WATER SOURCES IN THE HETAO IRRIGATION DISTRICT

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ABSTRACT

Hetao Irrigation District (ID) of Inner Mongolia located in north of China is one of three largest irrigation areas in China, where annual rainfall is ～150 mm. The Yellow River water is a dominant source for agricultural irrigation. With development of industrial and urbanization in the area, there are increasing contradictions between water supply and consuming in the area. A large scale drip irrigation must be developed to improve water use efficiency and to relieve the intensifying contradictions. This paper analyzes feasibility of drip irrigation development using three types of water sources and distribution area of drip irrigation development for every source (i.e. lakes, ground water and Yellow River water); 1) The wide distribution of lakes used as a source of drip irrigation water, which solves sedimentation and water storage problems, has certain development potential in Hetao area; 2) Three canals (Zonggan Canal, Shenwugan Canal and Dongfeng Canal) with shorter water supply cutoff days have the convenient water intake from Yellow River water and there is certain percentage of the wasteland for building sedimentation and water storage pools, the drip irrigation used with Yellow River water could be developed on certain size; 3) The development potential of drip irrigation using ground water is larger compared with other two water sources, but the appropriate proportion ratio between wells and canals irrigation area should be controlled. Based on the balance of exploitation and recharging to ground water, drip irrigation area using ground water may reach 6.67×10^4 hectares in the Hetao Irrigation Area.

Keywords: Hetao Irrigation District; Lakes; Ground water; Yellow River water; Drip irrigation development potential.

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BARLEY WATER AND NITROGEN REQUIREMENT TO INCREASE ITS SUSTAINABLE PRODUCTION IN SEMI-ARID REGION

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ABSTRACT

Barley (*Hordeum vulgare L.*) is one of the important cereals grown in the arid and semi-arid regions. Two-year field experiments were conducted to study the effects of different levels of water and nitrogen on grain yield (GY) and water productivity (WP_{GY} for grain) of barley (cv. Reyhaneh 0-3) in 2013-2014 and 2014-2015. Four levels of irrigation regimes (0, 50, 75, and 100 % of irrigation requirement (IR)) as main plot and nitrogen fertilizer (0, 70, 140 and 210 kg N ha^{-1}) as subplots were tried out with 3 replications in spilt plot design. All treatments received 100 mm of water as initial water for germination. Main effects of irrigation treatments showed that GY and WP_{GY} increased significantly with increasing in irrigation levels from rain-fed to 75% IR, whereas no significant difference was observed between 75 and 100% IR. Grain yield and WP_{GY} also increased by increasing nitrogen fertilizer rate. According to the result, maximum grain yield and WP_{GY} achieved at 75%IR with 140 kg N $ha^{-1}$and can be used as appropriate managements for winter barley in the study region in later. Further, because of soil initial nitrogen, the relation between applied water and nitrogen and grain yield showed that water played the main role for grain yield production under low level of applied water in comparison with nitrogen.

Keywords: Barley, Water, Nitrogen, Yield, Water productivity.

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USING DIFFERENT NUMERICAL SCHEMES FOR ASSESSING WATER PRODUCTIVITY

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ABSTRACT

In this research, the Analytic Hierarchy Process (AHP) and Analytic Network Process (ANP) were used to assess four different water productivity indicators of an irrigation network in Iran. To compare these indicators, seven criteria were selected and the indicators were weighted in both AHP and ANP models, using Super Decision 8.5 software. By using Delphi method and triangular fuzzy numbers, these models were transferred to Fuzzy AHP and Fuzzy ANP in order to distinguish and compare the pros and cons of AHP, ANP, FAHP and FANP. Comparing AHP and ANP models, the latter appeared to be a more robust model in multi criteria decision making. Physical economical water productivity and Total factor productivity have been concluded to be the most suitable water productivity factors and yield, while climate and water price were the most important factors affecting water productivity.

Keywords: Water Productivity, AHP, ANP, Fuzzy AHP, Fuzzy ANP.

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SOIL HYDRAULIC CONDUCTIVITY IN A NON-WHEEL TRAFFIC CORN ROW, A WHEEL TRAFFIC CORN ROW, AND A RECONSTRUCTED PRAIRIE

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ABSTRACT

Soil hydraulic conductivity is an important parameter for a model involving liquid flow and chemical transport processes in soil. Its value is affected by soil texture, structure, and porosity. These soil properties are influenced by plants, and by tillage and compaction. Our study investigated soil hydraulic conductivity in a non-wheel traffic corn row, a wheel traffic corn row, and a reconstructed prairie. The study area was located at the Iowa State University COBS (Comparison of Biofuel Systems) research site. Soil at the site was classified as Clarion soil (fine-loamy, mixed, superactive, mesic Typic Hapludoll). Soil hydraulic conductivity was obtained by steady-state tension infiltration measurements and numerical inversion of the Richards equation. The results showed that traffic compaction and a vegetation affected soil hydraulic conductivity over a range of water tension. At low water tensions, a non-wheel traffic corn row tended to have larger soil hydraulic conductivity than the other two treatments. However at relatively higher water tensions, wheel traffic corn row had larger hydraulic conductivity than the non-wheel traffic corn row, while prairie soil did not show distinct characteristic. The transition occurred at water tension of around 10 to 20 cm of water. At low water tension prairie soil had hydraulic conductivity larger than soil between corn rows with traffic compaction, but it had smaller hydraulic conductivity than soil between corn rows without traffic compaction. Prairie soil having smaller hydraulic conductivity than a non-wheel traffic corn row was unexpected. One possible explanation for the results is that prairie roots blocked some soil pores, thus hindering water flow.

Keywords: Hydraulic conductivity, traffic compaction, prairie, tension infiltrometer, HYDRUS.

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FORECASTING FOR HYDROLOGICAL DATA FOR RESERVOIR SIZING: CASE STUDY HUAI THA KOEI RESERVOIR

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ABSTRACT

Water inflow data is the main determinant of reservoir size. Water inflow is complex, influenced by rain, crops, soil and land use. Rainfall is uncertain in both time and space. Climate change increases the uncertainty of the rainfall.

HuaiTha Koei Reservoir is located in Mae-Klong River basin, in the west of Thailand. Its construction was completed in 2001 and continually operated for more than a decade. Historical runoff data of 27 years was used to design the reservoir size. However, after 10 years of operation, the measurements show that there is a change in both quantity and distribution of inflow.

This study applied the method of Phase Space Reconstruction (PSR) to forecast the inflow to the HuaiTha Koei reservoir. The same sets of monthly runoff data before the construction were used to forecast monthly inflow by using PSR method. While, the measured runoff data in the operation period of the reservoir between 2002 and 2013 were used to compare and evaluate the method. It is found that the value of variable that controls the PSR model including embedding dimension (m), delay time (τ) and nearest neighbor (K) are 15, 5 and 11 respectively. The comparison of the inflow between the model and actual measurement shows degree of consistency. The value of Correlation Coefficient (r) is 0.75, while the Efficiency Index is 54.04 and Relative Root Mean Square Error (Rel. RMSE) is 60.02. This PSR method can be effectively applied and used in conjunction with traditional inflow calculation method to forecast water inflow to revise the sizing of HuaiTha Koei Reservoir.

Keywords: Phase Space Reconstruction (PSR), inflow, runoff, Climate change, HuaiTha Koei, Reservoir, Thailand.

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A SIMULATION MODEL EVALUATING THE PERFORMANCE OF A RAINWATER HARVEST SYSTEM FOR IRRIGATION

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ABSTRACT

The difficulty for rainwater harvest (RWH) system implementation is to match the demand and the supply along with time. Because both demand and supply are stochastic, a properly sized storage may be critical for a success. Since the crop root zone can be thought as storage space in irrigation system design, operation and management, it may be much easier to use RWH in irrigation then in domestic demand supply. If the irrigations are operated carefully to match the rainfall pattern, more effective rainfall may be captured. An adequately sized storage farm pond may also be needed to store the excess rainwater for later use.

This study proposed a simulation model build under Microsoft Excel to simulate the RWH operations under different scenarios with different input combinations of climate, soil, crop, and storage sizes. The model will report back related evaluation parameters such as realized effective rainfall, total irrigation requirement other than the water supplied with the RWH, the optimum size for the storage facility, and the total pumping requirement if the water in storage need pumping to irrigate the field. These are all vital decision support information for both irrigation engineers and field irrigation managers in system designs and operations. The system manager may use this information to evaluate the feasibility to implement a RWH based on the irrigation demand reduction from the installation of the RWH pond. Also the irrigation operator may use this simulation tool to justify the allowable depletion level for best realization of effective rainfall capture.

The model was built as a daily model to reveal the fluctuation effects in climate factors (e.g. rain, temperature, humidity, wind) and crop (e.g.ET, Kc). The users may change the input parameters, such as allowable depletion before irrigation, maximum storage pond size, or initial water level in soil and storage farm pond, etc. The model is also potable for any locations by changing the input setting of climate, soil, and crop.

Keywords: Rainwater Harvest, Decision support, Irrigation management.

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THE PILOT PROJECT OF ENERGY SAVING AERATOR FOR WASTE WATER TREATMENT IN KHAO TAO RESERVOIR, THAILAND

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ABSTRACT

Nation-wide quality of water resources is facing severe problems due to organic pollution from municipal and industrial waste water. A waste water treatment prototype reactor using photo-electro catalysis technique employing sun light was designed for organic and coliform bacteria degradation. This prototype consists of titanium dioxide thin film on titanium photo anode electrode and titanium cathode electrode. The titanium dioxide electrode, after absorbing sunlight, turns water to hydroxyl radicals when an electrical potential is applied to the photo anode and cathode. The efficiency of hydroxyl radical generation can be increased with an optimum potential applied. For testing the prototype reactor efficiency, waste water from pulp paper industrial waste water and Doi Tung waste water, Chang Rai province was examined by the prototype. It was found that for pulp paper waste water COD value decreased from about 153 mg/l to 90 mg/l. For Khao Tao waste water COD value decreased by about 47.7-57.6%. Dissolved oxygen was increased from 4.22-5.94 to 7.40-8.10 mg/l. Turbidity was decreased from 3.2-4.8 NTU to 0.2-2.0 NTU in 6 hours. Coliform Bacteria was reduced from 11-18 colonies from 1 ml of water sample to 0 colony in 1-2 hours. Moreover, the prototype reactor was also used to test ground water quality from Kho Lanta, Krabi province, Thailand and found that coliform bacteria was reduced from 25 colonies from 1 ml of water sample to 0 colony in 1 hour. Therefore, the pilot project of energy saving aerator for waste water treatment in Khao Tao Reservoir demonstrated that the invented aerator can operated by solar cells, hence, saving energy and money to be paid for petrol. This aerator can treat water by reducing COD, decrease turbidity, increase dissolved oxygen, and reduce coliform bacteria. These parameters indicate that the invented aerator can be effectively used to treat and improve water quality in the reservoir.

Keywords: Energy Saving, Photo-electro catalysis, Water quality, Waste Water Treatment, Thailand.

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FRUITLOOK: A SPACIAL APPROACH TO ASSESS AND IMPROVE WATER USE EFFICIENCY OF VINEYARDS AND DECIDUOUS FRUIT ORCHARDS IN SOUTH AFRICA

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ABSTRACT

Water is a critical resource in South Africa, which challenges the irrigated agricultural sector to explore innovative solutions to improve the use thereof. New technologies developed, using satellite data, show the spatial and temporal variations of the actual crop water use, growth and N content at field level and helps farmers to improve their production and reduce the inputs and costs. FruitLook uses this technology to offer weekly updates for grape and deciduous fruit producing areas in the Western Cape through the web-portal www.FruitLook.co.za. All users, such as farmers, researchers and farmer advisors could evaluate the service for free during the irrigations season of 2011/12 to 2015/16.

FruitLook makes use of a processing framework that utilises a number of algorithms (e.g. MeteoLook, SEBAL) and satellite (DMC, VIIRS, MSG, Landsat 8 and Sentinel-2 images) and field data (weather) to produce data maps of nine parameters related to crop water use, growth and mineral content.

The accuracy of the parameters, specifically evapotranspiration, is important.Field work was done to estimate the evapotranspiration and was used to determine the data accuracy and further improve the algorithms. FruitSupport will warn users via emailif a significant increase in variation occurs within an irrigation block.

FruitLook is a project to assist irrigators to optimize their water use efficiency and is funded by the Western Cape Provincial Department of Agriculture.

Keywords: Vineyard, deciduous orchard, water use efficiency, SEBAL, South Africa.

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TUBEWELL RUN ON SOLAR ENERGY AND ITS USE IN AGRICULTURE

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ABSTRACT

Solar powered tubewell can be considered as a reliable and affordable source of supplying irrigation water compared with electric or diesel operated tubewell due to frequent load shedding and soaring energy prices. A two year study from 2012 to 2014 was conducted on solar powered tubewell installed at the Water Management Research Centre (WMRC), University of Agriculture, Faisalabad to investigate the viability of a solar powered tubewell in terms of its discharge and benefit cost ratio. The tubewell discharge was 51 m^3hr^{-1} having total dynamic head of 30 m. The depth of bore was 31 m (14 m blind +17 m screen) having casing diameter of 15.2 cm (6 inches). A 3-stage submersible pump of 10.2 cm (4 inch) diameter was lowered in casing to depth of 22 m. The pump was powered from 21 solar panels of 200 W capacity each. In winter the discharge of solar powered tubewell varied from 19.8 to 45.9 m^3 hr^{-1} and in summer it ranged from 23.2 to 43.7 m^3 hr^{-1}. The tubewell peak discharge was observed as 5 and 6 hr day^{-1}in winter and summer, respectively. Sugarcane was sown and irrigated with water pumped from solar operated tubewell and produced 118.6 $t.ha^{-1}$ annually. The breakeven analysis of solar powered tubewell vs diesel operated tubewell showed that the payback period of solar powered tubewell was 2.2 years of its 10 year usable life with IRR (internal rate of return) of 41 %. The BCR (benefit cost ratio) of solar powered tubewell at 2, 4, 6, 8 per cent discount rate were 2.77, 2.55, 2.36 and 2.19, respectively. The NPV (net present value) of solar powered tubewell at 2, 4, 6, 8 % discount rate were 1.39, 1.19, 1.03 and 0.88 million rupees, respectively. These results indicated that the solar powered tubewell is a viable option. Besides, it is environment-friendly and can be used by the farmers due to affordable payback period.

Keywords: Solar powered tubewell, benefit cost ratio, payback period, NPV, IRR.

Sub-theme 1

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EFFECTS OF BORON AND SODIUM TOXICITY ON THE GROWTH OF LEAFY AMARANTH (Amaranthus Cruentus)

Adeniran, K.A.[1], Amodu, M.F.[1], and Adelodun, B[1]

ABSTRACT

Boron and sodium toxicity on the growth and yield of leafy amaranth (Amaranthus cruentus) crop were studied using 4 x 2 factorial in Randomized Complete Block Design (RCBD), replicated thrice. The treatments included: no-Boric acid and no-NaCl salts, 5 mmol/cm of Boric acid and 20 mmhos/cm of Sodium Chloride, 15 mmol/cm of Boric acid and 40mmol/cm of NaCl and 25 mmhos/cm of Boric acid and 60 mmol/cm of NaCl. Interactions between treatments were also considered. Equal amount of irrigation water was applied manually and the same level of fertilizer was imposed on the treatments arranged in pots. Plant height, numbers of leaves, leaf area, root length and plant weight were determined and statistically analyzed. The results show that amaranth plant was affected by simultaneous salinity and boron toxicity. Plots treated with minimum toxicity; 5 mmol/cm of Boric acid [$B(OH)_3$] and 20 mmol/cm of NaCl (B_3NaCl_1) recorded the highest fresh and dry matter accumulation on the seventh week, 52.6g and 7g respectively, while treatment with Boric acid [$B(OH)_3$] and 40 mmol/cm of NaCl (B_3NaCl_3) recorded the lowest fresh and dry matter accumulation of 7.8g and 1.7g respectively for the same period. Plots treated with 5mmol/cm of Boric acid [$B(OH)_3$] and 20 mmol/cm of NaCl recorded the lowest values of 26.8cm, 16.1cm, and 38.5 cm^2 for plant height, root growth and leaf area respectively. The highest plant height and leaf area values of 23.3 cm and 102 cm^2 was recorded for plants treated with B_2NaCl1 during the eight week of growth. The results show that the low sodium chloride combined with moderate boron acid concentration favours crop growth.

Sub-theme 1

Keywords: Boron, sodium toxicity, Amaranthus cruentus, Boric acid and Sodium Chloride.

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Sub-theme 2

Papers Presented Under

SUB-THEME 2
Management of climatic extremes with focus on floods and droughts

Topics

2.1 Adaptation of design and operation criteria for irrigation and drainage schemes in light of climate change impacts

2.2 Managing impacts of extreme events – floods and droughts

2.3 Dealing with climate change impacts on food security

2.4 Regional water management in Asean countries and international river basins

INSTITUTIONAL AND AGRONOMIC APPROACHES ON DROUGHT MANAGEMENT AND SOME MAIN CROPS CULTIVATED IN TURKEY

Nese Uzen[1], and Oner Cetin[1]

ABSTRACT

Drought is caused due to a prolonged shortage of water, usually of precipitation. Turkey is located in the Mediterranean region and experiences widespread droughts of various intensities. Turkish Cabinet decided on 'Procedures and principles to combat agricultural drought in 2007. The aim of this decision is to help lessen the impacts of a possible drought with the participation of related ministries, universities, governorships, local governments and NGOs under the coordination of Ministry of Food, Agriculture and Livestock. However, lack of cooperation among the stakeholders still affects inappropriately drought and water management. On the other hand, climate variability is one of the most significant factors influencing year to year crop production. Cotton and winter wheat are the main crops cultivated in Turkey. Drip irrigation is the most effective method in terms of both maximum yield and water conservation for cotton. Sprinkler irrigation results in a lower yield than furrow irrigation in the South-eastern Region of Turkey. The reasons for a lower cotton yield with sprinkler irrigation might be attributed to high temperature and irrigation during the day time, very low relative humidity, relatively high wind speed in summer as well as the impact of sprinkler drops on cotton flowers and leaves. For winter wheat, as the economic maximum fertilizer nitrogen, the rates of 70 kg N/ha under non-irrigation conditions and 170 kg N/ha under irrigated conditions can be recommended. However, in case of drought occurrence, the rate of 120- 130 kg N / ha may be used under irrigated conditions. If the farmers get information and/or data about climatic and drought, the farmers should be avoided full fertilization as occurred normal amount of rainfall and distribution. The farmers should be, thus, used yield-response curve pertaining each region to get an economical yield. Knowing impacts of climate variables on the crops could enable to use efficient irrigation scheduling and to avoid excessive fertilizers. In this article, the institutional approaches of drought management and the effects of irrigation and climate variables on some main crops cultivated in Turkey have been discussed.

Keywords: Drought, climate, action plan, irrigation, cotton, wheat, Turkey.

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DIAGNOSTIC ASSESSMENT APPROACH FOR FORMULATING A CLIMATE-PROACTIVE MODERNIZATION STRATEGY FOR SMALL-SCALE NATIONAL IRRIGATION SYSTEMS IN THE PHILIPPINES

Mona Liza F. Delos Reyes[1,2], and Bart Schultz[1]

ABSTRACT

The publicly funded national irrigation systems (NIS) in the Philippines could only irrigate an average of 67 - 75% of their service area despite considerable rehabilitation and improvement efforts. The assertions coming from different stakeholders on the reasons for this relatively low performance included technical, managerial, institutional, policy and, in recent years, climate change. While the stakeholders would easily agree that each of the problems raised contributes to mediocre performance, a consensus on what is the right approach to address these constraints is hardly reached. Diagnostic assessment is a performance evaluation method specifically aimed at identifying the bottlenecks of irrigation system performance and, hence, appropriate approaches and solutions to address them. Diagnostic approaches for irrigation performance assessment have been carried out in a number of studies. It is considered a crucial prelude in the modernization process. Unfortunately, system diagnosis is not a part of the planning and formulation process for system improvement projects of the National Irrigation Administration (NIA); hence it is rarely carried out. This study explored the utility of a logic design framework and the diagnostic tools of the mapping system and services for canal operation techniques (MASSCOTE) in two small-scale NIS to contribute to the development of an improved and systematic approach to identify the root causes and solutions.

The applicability of the water-related, external indicators of the rapid appraisal procedure (RAP) and the structures sensitivity assessment as diagnostic tools were limited by the lack of flow data and the infeasibility of field experiments due to tight rotational irrigation schedules and laissez-faire direct offtakes. A pragmatic approach using discharge-head relations, hydraulic flexibility concept and the findings from walkthroughs and interviews was adopted as an alternative. The results of the study show that inconsistency in the system designs and lack of, or poorly performing flow control structures, drought-vulnerable main water diversion structures and tropical cyclone-related damages were the main contributing factors to mediocre irrigation service and overall system performance. The present logic design framework, RAP internal indicators and capacity assessment focus on canal structures and operation. Inclusion of headwork aspects will make these techniques more relevant to adaptation actions to climate change. The utility of the proposed diagnostic assessment framework that examines logical coherence among the system objectives, physical components, system operation and water supply was demonstrated. This diagnostic approach has a system modernization orientation and, in particular, will be suitable for mostly ungauged, run-off-the-river type NIS.

Keywords: Irrigation system; d+iagnostic assessment; rapid appraisal; irrigation modernisation; climate change; Philippines.

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HYDROLOGY OF THE RECENT CALIFORNIA DROUGHT AND COMPARISON WITH PAST DROUGHTS

Maurice Roos[1]

ABSTRACT

Multiyear droughts place a lot of stress on water systems. Water years 2012-2015 turned out to be a severe 4 year drought in northern California. Other notable droughts of the past 100 years included 1918-20, 1924-26, 1929-34, 1976-77, 1987-92 and 2007-9. Using the Sacramento- San Joaquin 8 river runoff as a measuring base, water year 2014 was the 4th driest of the historical record. Water year 2015 was about 20 per cent better than the previous year 2014 on the Sacramento River, but was worse on the San Joaquin River system where 2015 was the 2nd driest year of record, exceeded only by the severe 1977 water year. For the combined 8 river runoff, the recent 2015 water year was the 6th driest in a record of 110 years. The 4 year runoff period, WY 2012-15, for the combined 8 river system was the driest 4 year set of record, exceeding slightly the previous low record of 1931-34. However, on the southern group, the 4 rivers comprising the San Joaquin River system, the runoff was by far the worst in a 115 year historical record and about 20 percent drier than any four years in a reconstructed record of 1100 years estimated from tree rings. The drought was most severe over central California, including the Central Coast, San Joaquin Valley and southern Sierra regions.

Keywords: Drought, Sacramento, San Joaquin, California Rivers, Runoff deficits.

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HYDROLOGICAL INFORMATION AVAILABILITY INDEX FOR WATER ALLOCATION DECISIONS IN IRRIGATION DISTRICTS

Alexander Kaune[1], Micha Werner[2], Erasmo Rodríguez[3], and Charlotte de Fraiture[4]

ABSTRACT

Hydrological information on water availability and demand is vital for sound water allocation decisions, particularly in times of water scarcity. However, water allocation decisions in the operational and planning phase are normally taken based on incomplete or uncertain hydrological information on the current situation, which may lead to socio-economic losses. A hydrological information availability index was developed for operational and planning phases for irrigation districts. This index includes scores for temporal, spatial resolution and period of record. This index was applied in three irrigation districts in Australia, Colombia and Costa Rica to assess the availability of hydrological information and the potential value of information for water allocation decisions. Contingency tables were generated for water allocation decisions in water scarce and water abundant situations. The highest index was found for the irrigation district in Australia. Irrigation districts in Costa Rica and Colombia show medium to low information availability. Using the results of the contingency tables, a link was established between low information availability and sub-optimal water allocation decisions. It was determined that the districts in Costa Rica and Colombia have a higher potential value of information compared to the district in Australia. Additional hydrological information based on ground measurements, remote sensing, hydrological and global models can enhance water allocation decisions and reduce socio-economic losses.

Keywords: Hydrological information, water allocation decisions, irrigation districts.

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IMPACT ASSESSMENT OF CLIMATE CHANGE ON DESIGN FLOOD USING NON STATIONARY I-D-F CURVE BASED ON RCP 8.5 CLIMATE CHANGE SCENARION

Se Jin Jeung[1], Suk Ho Lee[2], and Byung Sik Kim[3]

ABSTRACT

The traditional hydrologic frequency analysis assumes that climate, and hence the frequency of hydrologic events is unchanging over time. But, Hydrologists have always known our world is inherently non-stationary, and they routinely deal with this in management and planning. The goal of this paper is to give a brief introduction to non-stationary extreme value analysis methods and how does climate change effect on Design flood estimation in Korea. The design approach of the drainage system has limitation not to consider the extreme rainfall condition of which I-D-F curve is non-stationary by climate change and variability.

In this paper, design rainfall by rainfall duration and non-stationary I-D-F curve are derived by the conditional GEV distribution. Furthermore, the effect of design flood with increase of rainfall intensity was analyzed by distributed rainfall-runoff model, S-RAT. Although there are some difference by rainfall duration, the traditional I-D-F curves underestimates the extreme rainfall events for high-frequency rainfall condition. As a result, this paper suggests that traditional I-D-F curves could not be suitable for the design of drainage system under climate change condition.

Keywords: Climate change, Non-stationary, I-D-F curve, S-RAT, Design flood.

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ECOLOGICAL RESTORATION AS A TOOL TO IMPROVE THE ECOLOGICAL RESILIENCE OF COASTAL RECLAIMED AGRICULTURAL LAND

Namjoo Heo[1], Sunghee Lee[1], Seona Yun[2], and Young D. Choi[3]

ABSTRACT

One of the most urgent challenges we face in the era of climate change is how to cope with environmental uncertainty. Thus far, the predominant solutions have relied on engineering. However, focusing on increasing the "resistance" of artificial structures alone is too limiting in the context of an unpredictable, rapidly changing environment. A feature of natural ecosystems, "ecological resilience", should be considered as well. Ecosystems can sustain themselves by reducing and regulating the impacts of external stressors and by restoring themselves when damage occurs. Two effects, which arise from the concept of "BDEF (biodiversity-ecosystem functioning)," create the setting for resilience: sample effect (large samples are less vulnerable to disturbance) and interaction effect (diverse samples have more interactions). Ecosystems also provide "ecosystem services," which are flexible, versatile functions that engineered infrastructures do not offer. Cultural and economic benefits we have received from natural ecosystem can be included in this service. Two approaches are proposed to improve the resilience of coastal agricultural land.

The first is to restore the resilience of degraded ecosystems in coastal itself. Coastal ecosystems' natural resilience is relatively strong, because they are linked to open marine ecosystems. The second is to improve the resilience of engineered infrastructures by hybridizing natural components (green infrastructure) with artificial facilities (gray structure).

Keywords: Ecological restoration, BDEF, Ecosystem service, Green infrastructure, Trade-off.

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FLOOD FREQUENCY ANALYSIS FOR EXTREME EVENTS UNDER CLIMATE CHANGE IN YOM RIVER BASIN OF THAILAND

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ABSTRACT

Changes in the flood frequency are expected under global climate change. We seek to utilize the hydrological model HEC-HMS for estimating extreme flood characteristics in Yom river basin. Historical rainfall and flood data in combination with rainfall products from MRI-AGCM3.2S (the latest version of GCM developed by MRI, Japan) were employed for HEC-HMS model calibration. For some parts of the basins with limited streamflow and rainfall data, HEC-HMS with Snyder's hydrograph synthesized and transposed methods were applied using calibrated hydrological parameters from the upstream sub-basins with adequate continuous daily records during 1978-2006. The simulations were accomplished at 10 stream gauges in Yom basin for extreme events occurred in 2000, 2002, and 2004. Execution of the watershed hydrologic model HEC-HMS yielded the annual maximum flood characteristics of interest. The flood-frequency relationships generated by the flood model were used to estimate the Annual Exceedance Probability (AEP) of selected flood characteristics in Yom river basin of Thailand.

Keywords: Extreme Flood, Frequency Analysis, Climate Change, Chao Phraya River Basin, MRI.

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NUMERICAL SIMULATION OF PERFORMANCE OF AN IMPROVED SUBSURFACE DRAINAGE SYSTEM USING HYDRUS-2D

Yuan Tao[1], Shaoli Wang [2], and Di Xu[3]

ABSTRACT

New requirements are put forward for agricultural drainage system due to frequent floods and shortage of cultivated land in China. The improved subsurface drainage is made more efficient by laying high permeability materials as filter above the drains based on conventional subsurface drainage whose function is limited by soil hydraulic conductivity. The HYDRUS model was used to evaluate the impacts of design parameters of filter hydraulic conductivity, filter width and height, drain spacing and depth on drain discharge with constant ponding depth. Besides, water table depths at different distances from the drain pipe for improved and conventional subsurface drainage were simulated under initial conditions of saturated soil and no water ponding. The results indicated that the improved subsurface drainage had a real-time drainage function for the reason that the cumulative outflow increased by about 58% than conventional subsurface drainage within 24h after beginning draining. Improved subsurface drainage lowered the water table to an appropriate depth faster than conventional one. Furthermore, through daily water balance analysis of improved and conventional subsurface drainage with different rainfalls and initial water table depths, the results showed that subsurface drainage could reduce surface runoff effectively, especially for improved subsurface drainage. Good drainability of improved subsurface drainage was beneficial to decrease the amount of soil water storage after rainfall and helpful to shorten subsequent draining time of water table drawdown. The research results could provide scientific basis for improved subsurface drainage design and lay a good foundation for its application. Meanwhile, it would be beneficial to enrich agricultural drainage technologies and promote development of agricultural drainage in China.

Keywords: HYDRUS, improved subsurface drainage, conventional subsurface drainage, discharge, water table, runoff reduction.

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MEASURES FOR EFFECTIVE USE OF AGRICULTURAL GROUNDWATER IN JEJU, S. KOREA

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ABSTRACT

The largest island in Korea, Jeju, is an aspite island, which depends on groundwater for the use of water resources. The majority of economic driving forces in Jejuare tourism and agriculture. Therefore, establishment and use of irrigation system using groundwater is the greatest issue in this region. Since the first success in developing groundwater by the Korea Rural Community Corporation in the 1970s, 96% or more of agricultural water usage in Jeju is supplied through 905 public wells, and the amount is up to approximately 693,900m^3/day as of 2015. However, the issue of agriculture water supply is continuously raised due to the change in water balance in this region. In particular, the cyclic and severe droughts in the past and the continuous intrusions of saline groundwater at west coastal area of Jeju have driven the establishment of new water supply system. Thus, the measures for effective groundwater use has been studied since 2013. As a result of this study, “Integrated Agricultural Water Supply System” was designed. Currently, this program completed, pilot projects in 2 zones and is now under operation system check. This program will be implemented for 8 years after such pilot project, and the budget for this amounts to $140million. When this program is completed, it will prevent drought damage permanently and solve the issue of lack of agricultural water, which in turn will increase agricultural yield and lead to the increase of income among farmers. In addition, expected indirect effects include effective preservation of groundwater due to enhanced public groundwater control, improved ability to respond to drought due to supply line linkage. It will become a model case for the effective use of water resources.

Keywords: Public Wells, Seawater Intrusion, Integrated Agricultural Water Supply System.

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ADAPTATION OF IRRIGATION UNDER CONDITIONS OF POSSIBLE CLIMATE CHANGES IN THE SOUTH OF RUSSIA

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ABSTRACT

According to the forecasts of The Voyeykov Geophysical Observatory, the additional increase in temperature by 0.6°C should be expected in the South of Russia by the end of the XXI century (http://rosnauka.ru/publication/844). In the case of the aggressive anthropogenic scenario the average-temperature will rise by 5-8°C in all parts of our country (Ivanov, A. L., 2003). Climate change directly affects agriculture and it is one of the serious constrains to the prosperity of the country. Temperature growth will lead to the increased areas of agricultural land. The increasing frequency of extreme weather events, changing rainfall and temperature leads to lower yields and decreases agricultural sector in GDP.

To ensure the adaptation of agriculture and reclamation under changing climate, irrigation plays a significant role. Irrigation was developed in the South of the European part of Russia with the aim of providing the population with rice, vegetables, cereals and fodder crops. However, since the early 90-s the reduction of irrigated area was caused by the processes of the national economy restructuring. According to the land reclamation cadaster of the Ministry of Agriculture, the area of irrigated land has decreased by 32%. This was caused by the deterioration of the irrigation systems and land reform.

In productive years more than 20% of all agricultural commodities of Russia are produced in the Southern Federal district (SFD), a major part of the irrigated lands being located there too. Water consumption in agriculture is stable and ranges from 30 to 55% of total water consumption in the country over the last 15 years, which should be considered when evaluating water availability and water pollution caused by drainage flow and runoff from irrigated agricultural lands. Therefore it is important to estimate the impact of the global warming and especially the adaptation of agriculture and irrigation under changing climatic conditions in this region. This requires valid prediction of changes in water availability of the territory on the basis of existing models of soil – climatic zoning and the possibility of crop productivity control for major crops.

Keywords: Global climate change scenarios, humid, arid, precipitation evaporation ratio, productivity, irrigation, drainage.

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MODELING IRRIGATION SYSTEM FOR WATER MANAGEMENT OF A COMPANION AND INTER CROPPING FIELD IN CENTRAL TAIWAN

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ABSTRACT

In Taiwan, most irrigation water distribution depends on manual operating. Furthermore, irrigation water loss from the conveyance cannot be accurately calculated. The situation turns worse as the climate change leads to uneven rainfall, both spatial and temporal. If the agricultural water usage, which accounts for 70% of total nation's water usage, can be allocated more precisely and efficiently, it would improve water resource allocation effectivity. This study applies system dynamic model to establish irrigation water management model for a companion and inter cropping field in central Taiwan. Combining rainfall and irrigated water was considered in the supply side, the model simulated two scenarios by decreasing 30%, and 50% planned irrigation water in the wet year 2013. The result shows that field storage of the end rotation of the study area, will be lower than wilting point, under 50% decreased water of irrigation plan only. It appears that the original irrigation plan can be reduced to be more efficient, and when stricter drought occurs, 50% reduction of irrigation can be applied as a solution of water shortage, however, it's suggested to implement adjustment of water gate more frequently for ensuring of the downstream rotation areas to obtain allocated water.

Keywords: Field capacity, Precision irrigation, VENSIM model, Irrigation Plan.

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REVITALIZING AND PREPARING DRAINAGE OPERATION AND MAINTENANCE TO ANTICIPATE CLIMATE CHANGE IN SEMARANG HERITAGE CITY

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ABSTRACT

In Semarang urban coastal areas are experiencing tidal flood. In addition, land has been subsiding by 5 to 10 cm per year. Flood risks associated with climate change have been inundating low lands from time to time. Semarang Old City (heritage) as part of principal Semarang area is suffering also from regular flooding and pollution that hamper the revitalisation of the old city. These areas used to be productive land, but flooding make the existing public infrastructure does no longer function, and residential areas have changed into unhealthy slums. To overcome these problems, the Government of Semarang chose a polder drainage system to address the flooding in Semarang. In the framework of the cooperation between Indonesia and the Netherlands, these activities consist of research and workshops on Urban Heritage. The scope consisted basically of five components: experiences with urban drainage and flood protection in Semarang with a focus on Semarang Old City, field visit to relevant places with respect to urban drainage and flood protection of Semarang Old City, lectures on the relevant aspects of urban drainage and flood protection, exercises to get an insight in the processes that can take place under normal and extreme conditions, formulation of a preliminary plan to improve the situation with respect to urban drainage and flood protection of Semarang Old City. In this paper the various relevant points are described, scenarios analysis as well as the findings and recommendations for improvement of the urban drainage system and flood protection of Semarang Heritage City.

Keyword: Drainage, heritage city, revitalization, operation and maintenance.

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INCREASING THE RESILIENCE OF SMALL AND MEDIUM SCALE IRRIGATION SYSTEMS IN NEPAL

Simon Howarth[1], Sushil Tiwari[2], Prachanda Pradhan[3], Umesh Parajuli[4], and Keshav Sharma[5]

ABSTR ACT

Agriculture is a mainstay of the economy of Nepal, providing about 30% of the GDP and supporting livelihoods for the majority of the population. It is very vulnerable due to the monsoon climate as well as topography, and population growth has made land holdings too small to meet the subsistence needs of most people. Off-farm employment and rural-urban migration are increasingly important to supplement agricultural income. Irrigation is an important requirement for agriculture but, despite the long history of irrigation in the country, it is widely recognised that the sector is still in need of improvement, and that climate change will only make the situation worse.

This two-year study, funded by the UK Department for International Development (DFID) through the Climate Development and Knowledge Network (CDKN) draws on field studies of representative irrigation systems as well as analysis of climatic data and future projections to understand how farmers respond to an uncertain climate. Farmer perceptions and actions have been correlated with actual climatic data for the recent past, and related to future projections of climate change. Increases in peak flows are anticipated but, more importantly, small changes in timing, intensity and duration of rainfall coupled with increases in temperature have already influenced cropping particularly in winter. The ability of communities to adapt to climate and other changes depends on the strength of community-based organisations, the condition of infrastructure and the importance of agriculture in the local economy. Improvement of agricultural support services is needed to enable diversification into higher value crops, for which the growth of new markets resulting from rapid urbanisation and improved road access provides an opportunity. Catchment-level management is increasingly needed to manage water equitably, particularly as return flows from upstream systems form an important part of the inflow for downstream systems, and both technical and institutional improvements are needed at system level. Resilience needs to be addressed at individual farmer, community and irrigation organization levels.

Keywords: Irrigation, Climate change, Nepal, Farmer-management.

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EVALUATION OF IRRIGATION SUPPLY AND NPS POLLUTION BETWEEN CONVENTIONAL AND SRI WATER MANAGEMENT IN PADDY

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ABSTRACT

Agricultural Nonpoint Source (NPS) pollution is a key contributor in the degradation of water quality in Korea. SRI is getting to gain its NPS pollution control effects and a comparison study between the data of SRI and conventional practices (CT, SD and HD) from 3 different sites where independent projects were conducted for 3 years from 2010-2012. The 3-year average irrigation depth of the SRI was 336 mm, representing the reduction of 51.5%, 45.1% and 48.8% compared with the CT, SD, and HD, respectively, and leading to an average of 48.5%. The EMCz from the SRI was 1.84 mg/L (BOD), 5.65 mg/L (COD), 34.54 mg/L (SS), 2.55 mg/L (TN) and 0.26 m/L (TP), which turned out to be lowered about 47%, 46%, 50%, 20% and 38% for BOD, COD, SS, TN and TP, respectively, if compared with the average of other treatments. The SRI discharged NPS pollution load of 73.6 kg/ha (BOD), 226.4 kg/ha (COD), 1,384.2 kg/ha (SS), 102.1 kg/ha (TN) and 10.4 kg/ha (TP). SD and HD discharged 1.3~2.4 times and CT 1.0~1.65 times larger load than the SRI discharged. Both low concentration and drainage contributed to the low pollution loads of the SRI. It was concluded that the SRI significantly reduce both irrigation requirement and NPS pollution loads to conserve both water resources and water quality in rural basins.

Keywords: Irrigation supply, NPS pollution, SRI, conventional practice, Paddy.

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TEMPORAL VARIATION OF THE INTERACTION BETWEEN CLIMATE CHANGE AND AGRICULTURE WATER MANAGEMENT IN THE NILE DELTA

Waleed H. Abou El Hassan[1]

ABSTRACT

In an arid country such as Egypt, climate change can pose significant risks on food security. Climate change effects manifest in many ways through the changes in: rainfall, temperature, sea level, water availability and consequently, the agriculture activities. Adaptations to such changes are crucial to survive through their ill-effects. However, the lack of interactions among the different authorities responsible for climate change assessment leads to varying opinion. This calls for an urgent need of collaboration and integration of the concerned parties. In order to preserve food security in Egypt, assessment related to agriculture water management is required. First attempt to set mitigation actions was conducted by irrigation sector, in 1960, by implementing subsurface drainage system to prevent higher soil salinity in case of sea level rise. Irrigation improvement projects are needed to mitigate the impact of climate change on water scarcity by implementing water conservation techniques and control water pollution. Air temperature increased 2°C over the past 30 years; leading to higher crop ET, and consequently increase in irrigation water demand. However, this led to the need for determining producing heat, salt tolerant and high yielding varieties. Farmers adapted to the increase in air temperature by shifting the planting dates to earlier times and the agriculture sector helped by producing different short duration varieties. However, simulation models are used to predict the impacts of climate change on the yield of main crops. Responsibilities of climate change impact from economical point of view as well as drafting the agenda of implementation were considered which raised challenge to the kind of climate change responsible sectors in Egypt which raised the challenge to the climate change responsible sectors in Egypt. The direct responsibilities as well as the collaborative responsibilities of the concerned sectors are designed. However, the over-interaction of some sectors adversely affected the implementation of climate change strategy in Egypt. This study presents a well-designed mitigations and a base for future implementation.

Keywords: Water and agricultural, Climatology, Mitigation, Sectors interaction, Egypt.

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EL-NINO EFFECT ON WATER MANAGEMENT OBJECTIVE IN TIDAL LOWLAND RECLAMATION AREAS (ADAPTATION MODEL FOR CORN)

MOMON SODIK Imanudin, and Budianta, D and Bakri[1]

ABSTRACT

Phenomenon of climate change occurs almost every year and the real impact was felt in 2015 where South Sumatra suffered prolong drought due to the effects of El Nino. This condition made the majority of agricultural land was affected by drought and even fire. The study objective was to assess the effect of El Nino on the water management operating system as an effort to provide water for crops requirement. Crop adaptation model was implemented by using corn as a second crop and it was expected to maximize land use under dry condition and to protect land from fire hazards. The results showed that the network operation was the drainage system (opened gate) which implemented from June to August and water retention system (closed gate) was done from September to October. The water level has decreased from July to October. The peak water level was dropped to a depth of -190 cm below soil surface at the beginning of October. Water retention eeffort done by the farmers was too late because it should be done during less rainfall period in July. Water table depth was more than 190 cm so that corn experienced a water deficit and its production level was decreased to 6-6.5 tons/ha compared to its typical production level of 8 to 8.5 tons/ha. This means that the impact of the El - Nino events have lowered corn production by 25 %. This condition is still good by considering the fact that land can still be used and protected from fire hazards. Therefore, intensification of agriculture in wetlands had proved to be capable to prevent fire hazards.

Keywords: El-nino; tidal lowland; water management.

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MANAGING DROUGHT AND FLOODS IN CALIFORNIA, USA

W. Martin Roche[1]

ABSTRACT

In early 2015 California was in the fourth year of below average precipitation. Beginning in the late fall of 2015 and continuing into early 2016, precipitation caused by El Nino weather patterns increased significantly. This caused some minor flood damage and some opportunities for increasing groundwater and surface water storage and some relaxing of restriction of water use.

The four years of drought during 2010-2011 to 2014-2015, rendered the snowpack in the mountains as low as 20% of normal and natural runoff in the Sacramento River was less than 40% of normal in 2014 and 2015. A state of emergency was declared by the governor of California, and drought restrictions were implemented, which reduced urban water supply by as much as 36% in 2015 compared to use in 2013, with a state-wide goal of reducing water use by 25%. No specific restrictions were made for irrigation users; however water allocations from the federal Bureau of Reclamation for irrigation customers were significantly reduced.

Throughout California, urban water supply was reduced by 23.9 percent, slightly missing the goal of 25 percent. Savings for individual water agencies ranged from a low of about 13% to a high of over 37%. Irrigation water users also reduced their use of surface water, with some pumping increased amounts of groundwater and others fallowing some of their land.

While precipitation returned to near-normal in Northern California, the anticipated El Nino wet weather pattern almost entirely missed Southern California, where dry condition continued. Throughout the State there was only minor flood damage.

Water managers in the state are taking steps to maximize groundwater recharge, increase surface water storage, reuse wastewater, desalinate sea water, and promote water conservation. The State plans to spend up to $200 million on projects to capture storm water, including groundwater recharge basins. There are several proposed projects that would significantly increase surface water storage.

California, along with federal and local agency partners, has a system for predicting and managing major floods, and provides assistance for those impacted by flood events. The last major flood in California occurred in 1996 and 1997. In December 1996 and January 1997 storms brought large amounts of precipitation to California and other states in the western United States. Over a nine day period, over 51 cm (20 inches) of rain fell in some locations.

Keywords: Drought, Water Conservation, El Nino, Municipal Water, Floods, Water Storage, Groundwater Recharge, California, USA.

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EVALUATING IMPACTS OF CARRY-OVER IN AGRICULTURAL RESERVOIRS ON WATER SUPPLY DURING NON-IRRIGATION SEASONS USING PROBABILITY ANALYSIS

JeHong Bang[1], Jin-Yong Choi[2], Sung-Hack Lee[3], Sang-Hyun Lee[4], and Seung-Yeon Jung[5]

ABSTRACT

Agricultural reservoirs are principal water resource for paddy field irrigation in Korea, and a carry-over storage estimation of reservoir is important for irrigation during the next season. The aim of this study is to evaluate the impacts of the probability of carry-over storage in agricultural reservoirs during non-irrigation season on water supply at the next irrigation season. A linear regression analysis was conducted to obtain relational functions between two variables including cumulative precipitation in non-irrigation period and reservoir storage variation with the reservoir operation data from 2001 to 2010, and reservoir storage at the irrigation start day (1st April) was calculated with the function obtained. To evaluate the probability of the reservoir storages at the first day of irrigation on 1st April, last day of reservoir storages were assumed to fifty, sixty, seventy and eighty percent of the full storage as the initial condition, and the cumulative precipitation data during non-irrigated season for the analysis were collected for thirty years from1985 to 2014. With the reservoir storage data obtained, frequency analysis was conducted in order to analyze probability of filling 90 percent of reservoir storage at irrigation starting day. From the results, probability of higher initial reservoir storage for irrigation starting date is depended on the storage condition of the first day of non-irrigation season, even though it is indicated that probability of filling 90 percent of reservoir capacity at irrigation starting day is varied. The result of this study is expected to be used as a guideline for off-season reservoir storage management considering probability of storage variation.

Keywords: Drought, Reservoir operation, Non-irrigation period, Climate change.

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VISUALIZING SUBMERGENCE RISK OF FIELD CROPS IN THE MIDDLE REACH OF CHAO PHRAYA DELTA

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ABSTRACT

The great flood of Chao Phraya, Thailand in 2011 exemplified the difficulty in flood risk management under the changing climate. The middle reach of Chao Phraya around Nakhon Sawan is a flood plain where three tributaries, Nan, Ping and Yom join together. The area regularly inundates and it also acts as regulatory area to alleviate inundation damage in the downstream. The area is used for agriculture and the cropping pattern needs to be managed to avoid inundation damage.

We combined a simple grid-based inundation model, high-resolution DEM and time-series satellite image analysis to visualize flood risk for crop failure with the concept of adaptive flood risk management. Flood risk comprises probability, exposure determinants (nature of flood) and vulnerability. Some 95 floods were randomly simulated in different locations along three tributaries. Inundation occurs from lower altitude and propagates to neighboring grids when inundation reaches their altitudes. Such simple modeling is justified in the very flat topography and the accuracy of inundated area largely depends on the precision of elevation. For this reason we used LIDAR observation data over Chao Phraya with a horizontal resolution of 2m and a vertical resolution of 0.1 m. The probability was represented as the chance of the area being inundated as consequences of 95 floods. The exposure determinant was represented as the maximum depth of inundation. The vulnerability was represented as the frequency of crops being cultivated during the flood season. We used 8-day-interval time series Enhanced Vegetation Index (EVI) and Land Surface Water Index (LSWI) derived from MODIS satellite data to detect cultivation of rice and non-rice crops for 15 years between 2000 and 2014.

The probability was very high in the confluence zone with relatively low elevation. Maximum inundation depths were high not only in the confluence zone but also in areas protected by dikes, west to the confluence zone. Rice was cultivated regularly in all areas during the monsoon season except for the confluence zone. Total risk was calculated as a multiplication of the probability, the exposure determinant and the vulnerability. Field crops cultivated in the dike-protected area exhibited higher risk.

Cropping pattern can be re-monitored every year to update the vulnerability assessment. Monitoring and controlling cropping patterns will make a new path for adaptive flood risk management in this area.

Keywords: Crop failure, Adaptive flood risk management, Submergence, LIDAR

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FLOOD RISK FORMULATION ON LOW-LYING PADDY REGIONS AS AN IMPACT ASSESSMENT TOOL FOR EXTREMES

Hiroki Minakawa[1], and Takao Masumoto[1]

ABSTRACT

This paper discusses a flood risk assessment procedure applied to low-lying paddy areas using risk curves to show the relationship between flood damage and heavy rainfall scales. The damage in paddies denotes the amount of rice yield reduction, and damage estimation entailed three steps. First, a drainage analysis model that enabled us to reproduce the inundation process in low-lying paddy areas. Next, a diurnal rainfall pattern generator, which requires daily and hourly observed rainfall data. Finally, the scale of rice yield reduction was investigated through pseudo-flooding experiments with rice plants. Those scales provide the relationship between duration of inundation and the reduction of rice yields. These three components were combined to formulate risk curves. A low-lying paddy area, the Kaga three-lagoon basin in Ishikawa Prefecture, was chosen as an experimental target. Based on drainage analyses, the water depth and inundation period in the paddies were extracted, and reduction scales were used to estimate the yield reduction ratio of each paddy. Damage in paddies was calculated by multiplying the reduction ratio and normal yields in the area, and these results were employed as fundamental data in the risk assessment. As a result, we formulated risk curves for the relationship between the probability of rainfall amount and the damage in the region at present and in the future. The shift between these two curves was defined as the change in the risks in the region due in part to climate change. Sustainable countermeasures for flood prevention would rely on schemes and strategies based on this assessment method.

Keywords: Regional flood risk, Yield reduction of rice, Inundation on low-lying paddies, Impact of climate change.

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DROUGHT ANALYSIS ON MAIZE IN THE LUVUVHU RIVER CATCHMENT, SOUTH AFRICA

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ABSTRACT

Maize (*Zea mays* L.) is a staple food in South Africa. Under rain-fed conditions, drought is a major limiting factor for crop growth and development. Among the various indices of characterising drought, the Standardized Precipitation Evapotranspiration Index (SPEI) has the ability to combine a multi-scalar character with the capacity to include the effects of temperature variability and evapotranspiration to monitor droughts with respect to severity, duration, onset, extent and end. This study was conducted to analyze drought occurrences and severity at different probability levels in the Luvuvhu River catchment, using the SPEI. This was based on climatic data from seven weather stations (1975 to 2014) which represent the catchment fairly well in terms of climate, soil and topographical features. Reference ET was calculated by Hargreaves method. SPEI was based on the Log-Logistic probability distribution of the water balance (D) per growing season at a 4-month temporal scale. The index was then aggregated at different timescales following three consecutive planting dates (October, November and December), as all the farmers cannot plant immediately after the first significant rains due to non-availability of tractor services and other inputs. For drought analysis, a 120-day maize crop was considered and analysis was carried out for the whole growing period. The SPEI time series was then subjected to the non-parametric Spearman's Rank Correlation test in order to determine trends. Results indicated a high variability of drought conditions over the area. Probability levels at 10%, 20% and 50% revealed that mild drought conditions were the most frequent in the area, giving a return period of once in two seasons. Furthermore, it was observed that planting in October placed the crops at a higher risk of experiencing droughts, as compared to planting in November and December. Trend analysis indicated no significant trends except for weak increasing SPEI values at Thohoyandou, implying that the severity of drought decreased over time in this area. Therefore, such findings can provide valuable information as to how to plan for crops and develop plans for mitigating the impact of drought in a given area.

Keywords: Rainfall season, Smallholder farming, Water balance, Maize production.

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EARLY WARNING OF AGRICULTURAL DROUGHT AND CORRESPONDING IRRIGATION MANAGEMENT STRATEGIES – TAIWAN'S ADAPTATION EXPERIENCE

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ABSTRACT

Climate change has resulted in frequent and severe droughts, prompting many countries to develop early warning mechanism for drought and the corresponding adaptation strategies. In Taiwan, severe drought has given rise to stringent challenges in irrigation water management. Therefore, the government officials and research institutions have worked together to analyze the historical hydrological data to establish the early warning mechanisms and to develop the strategies to cope with agricultural drought.

Insufficient precipitation during autumn 2014 and spring 2015 caused severe droughts in Taiwan resulting in lowest ever storage in some of the reservoirs. Government officials monitored precipitation and reservoir water level and initiated adaptation strategies. These strategies included (1) announcing fallow of 43,659 ha farmland and subsidized associated stakeholders accordingly, which saved 409 million tons (MT) of irrigation water, (2) promoting rotation irrigation of paddy fields (including by groundwater) and hiring workers to assist in precise water allocation. In Chianan Irrigation Association in southern Taiwan, enhancing irrigation water allocation efficiency and irrigation rotation in major areas, saved 63 MT of irrigation water, preventing fallow in Tainan and supporting the public demand.

Due to the likelihood of intensifying of drought, the following strategies should be applied by government officials and irrigation associations: (1) diversifying irrigation water resources and enhancing the establishment of relevant laws and regulations, (2) developing and promoting the technology of intelligent water gate and precision irrigation to increase efficiency and reduce the risk of water shortage.

Keywords: Drought, Climate change, Irrigation management, early warning, Taiwan.

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BOLSTERING GROUNDWATER IRRIGATION WHILST CO-MANAGING DISASTROUS FLOODS AND DROUGHTS THROUGH INNOVATIVE SUBSURFACE SOLUTIONS

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ABSTRACT

Major advancements are needed to avert increasingly frequent water-related disasters globally, and especially in the developing country context. One such solution currently under development involves facilitating groundwater recharge with wet-season high flows to refill depleted aquifers in upstream regions of catchments, thus preventing downstream urban flooding and simultaneously providing additional groundwater for intensifying irrigated agriculture and mitigation of droughts. This solution we have named "underground taming of floods for irrigation" or simply UTFI (pronounced 'utfy'). Thoughtful planning and staging are needed when applying UTFI to ensure that the technical, economic, social, institutional and environmental risks are addressed in progressing from design to implementation.

The origins for UTFI began in the Chao Phraya River Basin where our analysis shows that major flood events in past decades could be accommodated within the vast shallow alluvial aquifers situated within and upstream of the flood prone areas and generate major earnings for rainfed farmers by dedicating relatively small proportion of land to UTFI interventions. Upstream farmers could be incentivized to become flood water harvesters to gain local benefits from increased agricultural production and mitigate floods downstream.

The economic benefits to the rural economy in the implementation areas and the wider public benefits from flood reduction appear to be substantial and make UTFI attractive and support the transfer of investments from downstream flood relief and restoration to upstream prevention. Pilot scale implementation has commenced on the Gangetic Plains in Uttar Pradesh, India to more clearly reveal actual performance, benefits, costs and trade-offs. The characteristics that lead to sustainable development models and raise awareness amongst local and higher level stakeholders needed for upscaling are being revealed. A similar process has recently started in northwest Bangladesh.

Keywords: Floods; Droughts; Resilience; Groundwater irrigation; Chao Phraya and Ganges basins.

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MODELLING JOINT RIVER BASINS MANAGEMENTS FOR MITIGATING THE DROUGHT AND FLOOD – A CASE STUDY IN UPPER CHAO PHRAYA RIVER BASIN THAILAND

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ABSTRACT

Thailand has frequently experienced floods and droughts during S-W monsoon and dry period, respectively. In recent decades, the severity of both has intensified from rapid economy/ urban developments and climate change impacts. This study uses an optimization model as a simulation tool to explore different alternative scenarios for possible approaches to improve water system management.

A monthly optimization model was built with LINGO representing the system framework of Nan and Yom river systems of the upper Chao Phraya River Basin, Thailand. All necessary components, representing inflow, outflow and storage of water were included in the model. Water demands were estimated for municipal, irrigation, and environmental water use sectors. The model was built with the consideration of easiness for scenario setup to simulate different drought/flood mitigation measures. Eight scenarios were tested based on the combinations of three alternatives, i.e. transferring water between the Yom and Nan River basins using bypass canals, constructing a new reservoir on the upstream of the Yom River, and reducing paddy area in the Yom and Nan River basins. As water transferring between the Yom and Nan River basins was enabled or when a virtual reservoir was added on the upstream of the Yom River, downstream flow was sufficient, and deficit in agriculture was smaller compared to base case which has no bypass and no reservoir on the Yom River. When both bypass canals and virtual reservoir were used in combination, downstream flow was sufficient with no deficit for agriculture.

Though a monthly operating model might not be able to catch the variation within shorter time period, it can be easily modified to weekly or daily models as input data becomes available. This study demonstrates the use of an optimization model as simulation tool for evaluating different scenarios, or as a tool to discuss with stakeholders for better management decisions.

Keywords: Nan basin, Yom basin, Chao Phraya River, Thailand, Joint river basins water management.

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STATISTICAL FORECASTING OF RAINFALL BY ENSO/IOD INDEX IN THE CHAO PHRAYA RIVER BASIN

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ABSTRACT

In 2011, Thailand suffered from severe floods and droughts that caused huge loss of life and property, especially in the ChaoPraya River Basin. Earlier, in 1993 and lately in 2015, Thailand experienced drought that affected the agricultural area severely. These hydrological disasters have indicated an urgent need to study rainfall and river flow to improve flood and drought alleviation policies and practices, and implement the forecasting systems to predict meteorological conditions leading to disastrous runoff occurrences. The spectral analysis, probability analysis and VARMA model are adopted to investigate and forecast rainfall. This paper aims to investigate the relationships between sea surface temperature (SST) and rainfall and the interaction based on water year occurrence pattern and forecast seasonal rainfall by using the sea surface temperature as the input variable.

The relationship between rainfall and SST reveals that ENSO leads Chao Phraya rainfall by about 2 - 3 months, while IOD index lead by about 1-2 months. The Nino 3.4 and IOD index can be used to indicate the drought phenomena especially the lead 2 month anomaly SST index in MJJ and NDJ. The evaluation of forecasting monthly rainfall by VARMA model shows that can capture well in magnitude of rainfall in early rainy season in drought year. Furthermore this VARMA model performs a good predicative seasonal rainfall at the early rainy (MJJ) in drought year. This research will offer application opportunities to enhance the support of water resources planning and management.

Keywords: Rainfall, flood, drought, Enso Index, IOD index, forecast, VARMA model, Chao Phraya Basin.

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ASSESSMENT OF CLIMATE CHANGE IMPACT ON METEOROLOGICAL DROUGHTS

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ABSTRACT

Climate change impacts on drought intensity and frequency are an important issue in water resources planning in future periods in watershed scale. The aim of this paper is to investigate climate change impacts on drought in Karoon3 watershed located southwestern Iran in the future periods. The atmospheric general circulation models (GCM) data under Intergovernmental Panel on Climate Change (IPCC) scenarios was used for this purpose. Standard precipitation index (SPI) as a drought index was selected and calculated using mean monthly precipitation data in Karoon3 watershed. SPI was calculated in 6, 12 and 24 months periods in order to be used for water planning issues. Statistical analysis on daily precipitation and minimum and maximum daily temperature was performed. LRAS-WG5 was used to determine the feasibility of future period's meteorological data production. Model calibration and verification was performed for the base year (1980-2007). Meteorological data simulation for future periods under General Circulation Models and climate change IPCC scenarios was performed and then the drought status using SPI under climate change effects analyzed. Results showed that differences between monthly maximum and minimum temperature will decrease under climate change and spring precipitation shall increase while summer and autumn rainfall shall decrease. The precipitation occurs mainly between January and May in future periods and summer or autumn precipitation decline and lead up to short term drought in the study region. It can be concluded that rainfed planting season in this region should be postponed for one to two months gradually and surface water resources should be saved for short term droughts in future periods.

Keywords: Climate Change impact, Drought Severity, Drought Frequency, Karoon3 watershed.

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ANTHROPGENIC AND CLIMATIC FACTORS: AS CAUSES OF DROUGHT DISASTER IN SUDAN

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ABSTRACT

Sudan is a typical of least developed countries in Africa which is highly vulnerable to climate change and climate variability. It has suffered a number of long and devastating droughts in the past decades, undermining food security and are strongly linked to human displacement and related conflicts. The vulnerability to drought is exacerbated by the tendency to maximise livestock herd sizes rather than quality, and by the lack of secure water sources such as deep boreholes that can be relied on during short dry spells. This paper is an attempt to highlight the acute problem of inefficient drought management. It relies on critical reviewing of the available literature and personal experience of the author. It is found to be caused by man-made (anthropogenic), as well as, natural factors. Man – made factors can be confined to deforestation and its related activities. Other man- made factors are: over-cropping, overgrazing, and overexploitation of ground water. Natural factors of drought and desertification has resulted in soil degradation. These factors led to an increase in the recurrence of natural disasters that are accompanied with loss of life and personal properties, incidences of diseases, poverty and malnutrition as well as negative socioeconomic impacts and social unrest .Remedies can be drawn through strengthening early warning systems and adoption of sustainable agricultural practices and reforestation programmes and using renewable energy sources which are abundant in Sudan.

Keywords: Anthropogenic and climatic factors, drought, social unrest, socioeconomic impacts.

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QUANTITATIVE ANALYSIS OF ELECTRICAL RESISTIVITY DATA FOR THE SAFETY OF SEA DIKE

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ABSTRACT

Electrical resistivity (ER) survey was used for delineating seawater inflow through sea dike and diagnosing the safety of sea dike. To identify the part of anomalous seawater inflow through the sea dike, we carried out ER survey including ER monitoring along the dike including anomalous regions. However, ER survey results can be affected by the drastic change of groundwater level affected directly by tidal fluctuation even though ER survey has been widely used to image the electrical properties of the subsurface because of the convenience of data acquisition and interpretation. To overcome the limitation, quantitative analysis approach using the relationship between pore pressure and ER data obtained from piezometers and automatic ER monitoring systems was applied. From the results of analysis, relationship between two components was appeared to be high so that ER survey without drilling for obtaining pore pressure data turned out to be applicable for estimating the anomalous region. Therefore, time-series data from monitoring system would be effective to determine the cause of subtle changes in ER of the dike.

Keywords: Sea dike, electrical resistivity, quantitative analysis, pore pressure, leakage.

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DYING LAKE CHAD: ADAPTIVE STRATEGIES TO CLIMATE CHANGE AND WATER SCARCITY OF THE LAKE CHAD BASIN

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ABSTRACT

The current situation of over 90% shrinking of Lake Chad has been described by the Food and Agriculture Organization (FAO) as an "ecological catastrophe". As noted by a former Nigerian President, Olusegun Obasanjo in 2015, Lake Chad may no longer exist in 30 years' time. Hence, we must ensure that the 47 million people who depend on this lake for survival are prepared for the worst possible scenario. There is an indication that the Nubian Sandstone Aquifer (NSA) which extends to Chad could be the sustenance of the lake. Rather than propose further huge expenditure in efforts to recharge the dying lake by inter-basin water transfer, it is realistic to face the fact that regardless of whether the lake level rises, is maintained or completely dries out, the basin is foreseen to experiencing increasing desertification, which in turn will result in increased food insecurity in the region. From robust water harvesting, adoption of water-saving agricultural practices, fishing and fishery activities regulation, water policy formulation and implementation to aggressive awareness of climate change, there is the need to prepare the dependent populace for the unpleasant economic, agricultural and political implications. Analyzing the current condition of the lake in comparison with other existing and preexisting surface and groundwater aquifers, combined with available research findings, this paper outlines adaptive strategies for the populace around the Lake Chad-with and without water.

Keywords: Lake Chad, Adaptive Strategies, Nubian Sandstone Aquifer, Groundwater, Hydraulic flow, Sustainable Livelihood.

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SOME LEGAL AND REGULATORY ADJUSTMENTS AVAILABLE FOR DROUGHT RESILIANCE

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ABSTRACT

In the arid western United States securing water resources in times of drought include increased reliance on pumping from the groundwater aquifers when snow-pack does not fill the storage reservoirs. This added strain on groundwater resources impacts surface sources as well, but unless the existing legal system regulates surface and groundwater conjunctively, water managers have little control on aquifer exhaustion. Legal avenues for securing water must include looking at a water system as a whole and not administering surface water separate and apart from groundwater systems.

Unfortunately, Nevada's legal system in the past has not considered the interconnection between the groundwater and surface water systems. Thus, the state has allowed continued appropriations of groundwater that have effectively drawn water away from the Humboldt River System, the system that would traditionally fill the irrigation District's reservoir. To add to this problem, there are several mines in the Humboldt River Basin. Nevada has allowed the mining industry to create large open-pits in pursuit of silver, gold and other valuable minerals, which pits intercept the aquifer discharge to the Humboldt River system. During this process, the mine must run constant de-watering pumps to keep the pits free from water. The de-watering water is either dumped on the ground a few miles away or sometimes piped to new agriculture production to the detriment of the prior appropriators. This pit water is not taken into account in water basin budgets.

The first step for Nevada is better water management, and managing the groundwater and surface water systems as one. If the total system is in balance through conjunctive management, and the system properly regulated, arguably the once drought-resilient system may come back to support agricultural production in northern Nevada.

Keywords: Drought resilience, legal assistance, groundwater, surface water, water laws, United States.

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HYDROLOGICAL DROUGHT INDEX AT THE IRRIGATION AREA IN PEMALI-COMAL RIVER BASIN

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ABSTRACT

Drought index is an important tool to detect the onset, ending, and severity of a drought event. Until recently there is no hydrological drought index has been accepted internationally. In search of promising hydrological drought index, this paper analyses the performance of several hydrological drought index at five irrigation weirs in the Pemali-Comal River Basin, Indonesia. The performance is measured by the correlation between the streamflow drought index and the irrigation areal affected by drought. This paper examines different kinds of hydrological drought index based on the Theory of Run. The combination of the index consists of: 1) moving averaged data of 1, 3, 6, and 12 months; 2) Normal, Log-Normal and Gamma statistical distribution; 3) fixed and seasonal threshold; and 4) threshold level of mean flow and dependable flow. The performance of the hydrological drought index is examined through their correlation with the historical data of irrigation area affected by drought. It is concluded that good correlation between index and the impact data generally: a) Index with 3 months moving average; b) Log-Normal distribution; c) Fixed threshold level; and threshold level of mean flow, except for original data of one month the dependable flow is better. Finally, the decision making impact of selecting a particular type of drought index from among others is not significant, for all of the index are be able to identify the drought events.

Keywords: Drought, drought index, hydrological drought index, irrigation.

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APPLICATION OF DWCM-AGWU MODEL TO THE MAE KLONG RIVER BASIN WITH LARGE COMPLEX IRRIGATION SCHEME

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ABSTRACT

The DWCM-AgWU (Distributed Water Circulation Model incorporating Agricultural Water Use) was applied to assess the water use in the Mae Klong River basin, especially amount of irrigation water for the Greater Mae Klong Irrigation Project during the years 2008-2015. The result of this application was also used to assess the limitation of the present model on the water requirements and water allocation sub-models for irrigated areas. The Greater Mae Klong Irrigation Project supplies irrigation water from two large reservoirs, the Srinagarind and Vajiralongkorn dams. The water is fed to these irrigated areas is considered a component of the water requirements of various agricultural activities, such as paddies, upland crop fields like sugar cane, as well as fisheries and perennial crop fields. As a result, in the present model, the amount of diverted water was considered as only that used by irrigation rice paddies. From this limitation, the modified model should be expanded to include the calculation of water requirement for other agricultural activities by using a database of crop coefficients of water requirement and cropping patterns. The new model will facilitate the development of adaptation measures against extreme events, especially drought and to evaluate the effectiveness of such measures. Furthermore, it enables us to evaluate and project the effects on water circulation in the basin brought about by various human activities (e.g., changes in agricultural practices) and meteorological changes from global warming.

Keywords: Complex irrigation project, Water requirement, Water management, Drought.

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INDUS BASIN DROUGHT (1999-2002) IMPACT ON IRRIGATED AGRICULTURE – A POLICY REVIEW IN THE PREVIEW OF MEGA STORAGES AND FLOODS

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ABSTRACT

The Indus Basin Irrigation System (IBIS) is prone to extreme floods and droughts and faces large economic losses, either due to excess or limited water supplies. Pakistan faced drought from 1999 to 2002, with a reduction in river inflows of 25% and a 12 to 25% drop in canal diversions in IBIS. In Sindh, there was maximum reduction in waterlogging due to low canal supplies. However, this accelerated salinity build up and lead to poor germination and low crop yields, particularly for the Rabi season. On the contrary, the aquifer storage in Punjab provided necessary resilience against the drought, though at the cost of groundwater mining; there was significant increase both in cropped area and total production. The other extreme natural calamity i.e. floods are more frequently faced than droughts. It happens due to extreme rainfall events and lack of surface storages in the river system. The most recent one was faced during 2010, with 1781 casualties and 2.2 million hectares of crop damages. Loss to irrigated agriculture was especially high in Lower Indus. Also, in 2011,436 mm rainfall in Mithi, Sindh, lead to heavy flooding which sustained for months. These losses can be gradually and outstandingly minimized with the help of a well-planned development program of mega reservoirs for the regulating surface flows as per requirement of dry and wet seasons.

Keywords: IBIS, Floods, Drought impact, Mega reservoirs, Lower Indus, Crop yields.

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THE STUDY OF NUMBERS AND INTENSITY OF TROPICAL CYCLONE MOVING TOWARD THE UPPER PART OF THAILAND

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ABSTRACT

The upper part of Thailand is an agricultural region where the rainfall from tropical cyclone (TC) is the main source for agricultural production. The analysis of meteorological parameters during 1951-2014 was in the relationship of TC trend and rainfall, the correlation between the annual number of TC and sea surface temperature (SST) as well as the numbers and intensity of the TC in each ENSO year. The study showed the decadal number of TC in 1951-1970 was significantly linear, decreasing from 3 to 1-2 in 2001-2010 and the annual average rainfall was decreasing about ten percents. The correlation coefficient of annual numbers of TC and SST was -0.4 to -0.6 meaning that the decreasing of these TC was corresponding to increasing of the SST in the South China Sea and the Western North Pacific Ocean. The numbers of these TC for El Nino, La Nina and Normal years were 24.3, 19.3, 48.6 percents and the intensity was categorized into depression and tropical storm. There were 121 depressions, 8 tropical storms that were 4 in El Nino, 3 in Normal and 1 in La Nina as well as no Typhoon. The occurrences of flood and drought events were not clarified because there were both flood and drought events in El Nino, La Nina and Normal years. Subsequently, for the existing of those events we concluded that they have depended on rainfall in terms of amount, distribution, frequency and related circumstance. Therefore, the further water management and planning in future should consider in aforementioned characteristics of rainfall and related matters as well.

Keywords: Tropical cyclone (TC), El Nino, La Nina.

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ON SUSTAINABILITY OF IRRIGATION DEVELOPMENT AND DISASTER MITIGATION OF THAILAND'S CHAO PHRAYA DELTA

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ABSTRACT

The Chao Phraya delta measuring 100 km along East-West and 180 km along North-South is the single most important rice growing area in Thailand. Its irrigated area of 1.2 million hectares produces about 8 million tonnes of rice. In addition, it also produces sugar cane and orchards crops. Its fertile soil, especially in the upper delta, makes it a major agricultural base in Thailand. It also houses the economic center of Thailand - Bangkok and its vicinities, including many industrial estates around. Whatever happens to this delta can create big effects on Thailand's economy. When the delta was still virgin, it was very inhospitable to live. There was no water for drinking in the dry season and in the rainy season the area was always flooded.

Settlement in the delta began after 1350 with orchards planted along river levees. Later on canals were dug for navigation and also for irrigation purpose. Large increase in export of rice which began after 1855 required good irrigation to supply water that old canal systems could not provide. The modern irrigation system was planned in 1902 but was implemented much later due to shortage of funds. The Chao Phraya barrage was completed in 1957 followed by two large storage reservoirs in 1964 and 1971. After that dry season cultivation of rice increased steadily. Although the government constructed more storage dams, the shortage of water supply from the reservoirs occurred quite often. In drought years, the problems of water shortage and water allocation became more serious e.g. in 2015 and 2016 some reservoirs were depleted to dead storage.

However, there are some plans to develop new irrigation areas within the Chao Phraya basin itself. This will create more water use and less inflow into the reservoirs. Careful consideration for limiting such development and proper allocation quantity must be studied to ensure sustainability of the existing irrigated areas.

Large floods such as in 2011 that caused extreme damages and losses shocked the people and authorities jumped to propose a flood protection system that is overly large, expensive and difficult to implement, operate and maintain. Large bypass new canals in soft soils may prove to be unfeasible and unsuitable. A proper mitigation program with adaptive mitigation measures that integrates all factors including the nature of the delta into consideration may better suit the situation and make the whole program sustainable.

Keywords: Chao Phraya Delta, Sustainability, Drought, Flood, Integrated management, Adaptive measures, Non-structural measures.

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CROSS-SECTORAL IMPACT OF WATER DEFICITS IN NAN RIVER BASIN

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ABSTRACT

Nan River Basin contributes about 25 to 40 percent of annual flows in the Lower Chao Phraya River Basin where main agricultural, manufacturing, service, and domestic water use sectors located. Water allocation during dry season depends mainly on the amount of water storage at the end of rainy season in the four main reservoirs in the upstream of the Chao Phraya River. However, impacts across sectors are also important in developing strategies to mitigate drought. Understanding cross-sectoral interactions from both water resources and economic point of view provide better insight in decision making. This study proposes a framework of cross-sectoral analysis of water allocation during dry season between three sectors (agriculture, manufacturing, and service and domestic) in the Nan River Basin with the consideration of impacts to the Lower Chao Phraya River Basin. An assessment model in this study is based on the water budget and the Input-Output model. Preliminary results of economic analysis of cross-sectoral impacts of water allocation in the Nan River Basin show the importance of considering interactions between sectors and non-hydrologic factors in developing strategies to mitigate droughts.

Keywords: Drought, Water allocation, Input-Output Table, Nan River Basin.

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ASSESSMENT OF AGRICULTURAL DROUGHT RESPONSES CONSIDERING RESERVOIR STORAGE RATES IN SOUTH KOREA

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ABSTRACT

The aim of this studyis to assesswhether the agricultural drought responses were conducted properly according to drought response guidelines in South Korea. The agricultural drought which causes long-lasting damage, requires the phased responses along with the progress of the disaster. Ministry of Agriculture, Food, and Rural Affairs (MAFRA) have categorizedstages of drought which mean theprogressof the agricultural drought into normal, concern, and proliferationstage about the severity and have established the recommended responses at each stage as guidelines.Reservoir storage rates which are used to indicate the drought severity and the drought responses are analysed with this rates as well as the guideline. The responseswere collectedfrom the practical worksconductedduringthe drought yearsincluding1994, 1995 and 2012.Assessment of the responses is conducted by the accordance between the stage in which the response was recommended by guideline and the stage which the reservoir storage rate indicated. The rates of accordancewere 41.2% (35 in 85 cases), 50.0% (12 in 24cases), and 8.3% (5 in 60 cases) in 1994, 1995, and 2012, respectively. The excessiveresponses to compare with the guidelines was found in 1994 and 2012. In all 3 years, the rates of accordance were 30.77% (52 in 169 cases),andthe drought responses had been hardly conducted step by step according to the reservoir storage rates. The results show that the drought responses practically conducted were more exesive than those recommended by the guidelines. Furthemore the actual drought responses have been conducted by arbitrary decisions, not the reservoir storage rates and the guideline.

Keywords: Agricultural drought, Drought responses, Drought stages,South Korea.

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FLOOD MITIGATION IN MONKEY'S CHEEK PROJECT AREA

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ABSTRACT

During floods, huge volumes of water need to be stored in rivers, canals, reservoirs, ponds, lowland or floodplain areas. However, if natural storage is not enough, excessive flood water will flow downstream and inundate economically important community areas, resulting in huge economic damage (eg., 2011 in Thailand. There are many flood mitigation measures but a method to alleviate flooding problem is to store water in the detention area known as Kaem Ling or Monkey's Cheek in Thailand. It is part of the Thai government's plans for flood mitigation and water management in the long run. A successful project is the Mahachai-Sanamchai Canal Monkey Cheek which stores flood water in the upper area and, at the same time, releases water into the Gulf of Thailand in relation to the tide levels of the sea by relying on the use of gravity and pumping stations. The project comprises improvement and construction of regulators and pumping stations in canals in the area of an irrigation project, which yields considerable alleviation of flooding problem as indicated by results simulated by a mathematical model simulation. This concept will be applied to lowland and irrigation project areas in the Yom and Nan River Basins—tributaries of the Chao Phraya River Basin, north of Nakhon Sawan province.

Keywords: Irrigation Project, Flood Detention, Mathematical Model.

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AGRICULTURAL DROUGHT FORECASTING AND WARNING SYSTEM

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ABSTRACT

Damage from agricultural droughts spread gradually on wide areas over a long period. In addition, due to climate change, the frequency and intensity of drought have increased. The drought of 2015 in Korea has been the worst due to lowest rainfall. It has been suggested that Korean government revisit the agricultural water management policy and incorporate in it the drought forecasting and warning system for effective drought management. In this study, new information of preparedness and mitigation planning for agricultural drought in Korea, including a long term plan and water saving strategy has been suggested. It analyzes the previous drought status using the agricultural drought map, the prediction information related to drought damages, and the drought-related response capability of irrigation facilities. The system can be used to provide current and future drought conditions and the comprehensive data of drought evaluation for supporting decision makers. Also, the agricultural drought forecasting and warning system can give an opportunity to build the proper response for agricultural drought holistically and systematically.

Keywords: Agricultural drought, Drought management, Drought forecasting, Drought policy, Climate change.

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CLIMATE AND DROUGHT TRENDS AND THEIR RELATIONSHIPS WITH RICE PRODUCTION IN THE MUN RIVER BASIN, THAILAND

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ABSTRACT

The variability in climate regime is an important factor contributing to rice yield variations in Thailand because nearly 80% of total rice cultivation is rain-fed. Here we investigated the past weather conditions using a drought index (SPEI) and examined correlations between rice yield and SPEI and other climatic variables (precipitation and temperature) in the Mun River Basin, Thailand. The results show increased occurrences of both wet (leading to floods) and dry (leading to droughts) climatic conditions in recent years. Rice yield tends to reduce with the rising trend of temperature, but may be compensated by increasing trend of precipitation. We found that) the maximum temperature is a better indicator for rice yield compared to mean or minimum temperature and precipitation, ii) 1-month SPEI is a better indicator than only precipitation, and iii) the 1-month SPEI is more strongly correlated with the rice yield than SPEI with other time scales, which should be used to monitor soil moisture and crop stress in rice. We also observed that rainfall in the basin is much less than the water requirements for rice and that average rice yield in Thailand is one of the least among the major rice producing countries in Asia. Therefore, irrigation and drainage systems supplemented by alternative sources of water in combination with innovative method of rice cultivation and efficient water management techniques should be introduced to enhance the rice yield. Our findings form a basis to quantify impacts of climate variability and change on rice production.

Keywords: Climate, Drought index, Rice yield, Mun River Basin, Thailand.

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DROUGHT AND FOOD SCARCITY IN LIMPOPO PROVINCE, SOUTH AFRICA

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ABSTRACT

The Limpopo province is one of the poorest province in the country, characterized by high unemployment rate, poverty and lack of access to a range of resources that frustrate majority of people's ability to secure their livelihoods.The aim of the study was to describe the drought status and food scarcity in Limpopo province. The following objectives were followed: (1) To describe the current rainfall and drought status in some districts in Limpopo province and (2) To describe factors that may influence food scarcity in Limpopo province. A representative sample of 300 farmers aged 18 – 60+ years also participated in the study. The following 10 local municipalities were visited: Elias Motsoaledi, Makhuduthamaga, Fetakgomo, Ephraim Mogale, Tubatse, Lepelle Nkumpi, Blouberg, Aganang, Polokwane, and Molemole. The purposive sampling method used to cover the uniform or homogeneous characteristics of farmers. Data was coded, captured, and analysed using SPSS. The following analysis were conducted: Descriptive and Regressions. The results showed a positive association among the following variables: Food scarcity, Gender, Information on climate change, Adaptation to climate change and Extension service received.

Keywords: Drought, climate variability, climate change, agricultural production, food scarcity, Limpopo province, South Africa.

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POSSIBLE EFFECTS OF CLIMATE CHANGE ON SUGARCANE DEVELOPMENT AND WATER USE IN SOUTHWEST OF IRAN

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ABSTRACT

Water and food security are the key challenges under climate change as both are highly affected by continuously changing climatic patterns. In this study, attempts have been made to study the effects of climate change on length of growing season and water use of sugarcane under RCP scenarios in 4 stations of Khuzestan province, southwest of Iran, namely Abadan, Ahvaz, Bostan and Dezful. The outputs of EC-EARTH global climate model data which are dynamically downscaled by Swedish Meteorological and Hydrological Institute (SMHI) under RCP 8.5 and 4.5 scenarios were used as future projections. The climatic observed data of 4 study stations were collected and used to calibrate the model down-scaled outputs. The changes of precipitation, crop evapotranspiration and length of growing period of sugarcane were worked out. The results showed that except for Dezful station, growing season rainfall would increase comparing to climatic normal. Besides, the length of growing season under RCP8.5 scenario would decrease significantly in all stations. Future trend of evapotranspiration changes was less than 5% and non-significant. Continuous investigation in other climates of the country is undertaken for further scrutiny.

Keywords: Sugarcane, Iran, Climate change, Scenario,CMIP5.

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ADAPTATION POLICY FOR AGRICULTURAL WATER MANAGEMENT FOR DROUGHT IN KOREA

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ABSTRACT

The Korean government has established an adaptation policy for dealing with droughts, based on three main directions for policy change. The first direction is to improve the water management scheme to ensure a more reliable water supply. The second direction is to change from fragmented actions to comprehensive measures for dealing with drought. The third direction is to put more emphasis on pre-drought measures than on post-drought actions. The adaptation policy consists of 16 specific action plans under four major strategies suitable for the successful implementation of comprehensive measures for drought management in agriculture and rural areas. Through implementation of these actions, the percentage of irrigated paddy fields can be increased from 60% to 80%, and the water supply rate for irrigated upland fields can be increased from 18% to 30%. In addition, the irrigation water loss from channel and farm practices can be reduced from 35% to 25%, and the rate of agricultural water reuse can be increased from 30% to 45%.

Keywords: Adaptation strategies, Drought, Agricultural water management, Climate change, Korea.

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TREND ANALYSIS AND UNCERTAINTY ESTIMATION OF THE EXTREME CLIMATE INDICES AND IMPACT ON AGRICULTURAL YIELD: A CASE OF TAMAKOSHI RIVER BASIN

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ABSTRACT

This research was carried out at Tamakoshi River Basin, a sub-basin of the Koshi River Basin in the NE of Nepal. Climatic parameters temperature and precipitation of the study area are projected to change in near (2010-2039), mid (2040-2069) and far (2070-2099) future. Both minimum and maximum temperature are about to change by a significant amount. The maximum temperature is projected to rise up to 1.75^{0}C under RCP4.5 and up to 3.52^{o}C under RCP8.5 whereas the minimum temperature is expected to rise by 2.1^{o}C under RCP4.5 and 3.73^{o}C under RCP8.5 by the end of the 21st century. The precipitation in the study area is expected to change by -2.15% under RCP4.5 and by -2.44% under RCP8.5 scenarios. The trend analysis of different precipitation and temperature indices reveals that the TXx, TNn, FD, TR has significant change over the future time window. The climate indices are changing at -0.05^{o}C/year, -0.02^{o}C/year, +0.05 days/year and +0.43days/year respectively. Similar significant change in case of precipitation indices has observed in the study area. It was thus concluded that the hydrological regime would be affected seriously and thus the discharge of the catchment area.

Keywords: Climate change, Regional Climate Models, Extreme Climate Indices, Uncertainty Estimation, ANOVA, Agricultural Yield.

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WATER FOOTPRINT OF PADDY RICE USING FAO-AQUACROP UNDER CLIMATE CHANGE IN SOUTH KOREA

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ABSTRACT

Climate change will cause changes in rainfall patterns and drought frequency and both will impact on water management and crop production. This is a critical issue in agriculture industry. In addition, water supply has inter-relationship with crop production which indicates water productivity. Therefore, it is important to assess overall impacts of climate change on water resource and crop production. “Water footprint” is an indicator of water use in relation to crop yield. It generally breaks down three components depending on water resources: green, blue, grey water. This study analysed the water footprint of the impacts caused by climate change on paddy rice in South Korea. In this study, Medium-late rice maturity type and future climate data was collected from HadGEM3-RA based on RCP8.5 scenario from 2010 to 2099. Suwon (Gyeonggi province) and Jeonju (Jeonbuk province) were selected as a study area. The FAO-AquaCrop 5.0, a water-driven crop model, was calibrated for the baseline (1996-2015). Model was validated by Mann-Whitney U test and was used to simulate rice yield for future period. The means of water footprint are projected to increase by 55% (2020s), 51% (2050s) and 48% (2080s), respectively, from the baseline value of 767m^2/ton in Suwon. For Jeonju, total water footprint was projected to increase by 46% (2020s), 45% (2050s) and 12% (2080s), respectively, from the baseline value of 765m^2/ton. However, the climate change data include uncertainty of GCMs, thus the uncertainty of estimated water footprint was analysed. The results of this study could provide basic data for agricultural water management to cope with climate change.

Keywords: FAO-Aqua Crop, Water footprint, Green water, Blue water, Climate change.

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MODELING THE IMPACT OF ANTICIPATED SEA LEVEL RISE ON THE NILE DELTA AQUIFER SYSTEM IN EGYPT

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ABSTRACT

The average sea water will rise as an expected impact of climate changes. The Nile Delta, as most Deltas around the world, is facing coastal problems of accretion and erosion that will be aggravated by rise of sea water level. The main objective of this study is to assess the impacts of climate changes/sea level rise on the behaviour of Nile Delta aquifer. A 3D variable-density groundwater regional flow and coupled salt transport model has been constructed for the Nile Delta aquifer system. The regional simulation of the Nile Delta aquifer used all the new acquired data on heterogeneity and hydro-chemistry; these data have been harnessed in the modelling process using SEAWAT program. The calibrated model has been used to calculate the expected seawater intrusion resulting from sea level rise scenarios in the Nile delta aquifer based on the variable density technique. The impact is assessed in terms of movement of fresh/saline interface within the Nile Delta aquifer. The study utilized the calibrated and validated model, both in terms of hydraulic heads and salt concentration to assess the impact of sea level rise on the Nile Delta aquifer system under sea rise scenarios of 50 cm and 100 cm after 50 years. The results of assessing the impacts of sea level rise scenarios have confirmed the negative impacts that could occur from the expected sea level rise on the salinity of the fresh groundwater which will extend to reach the bottom vertex of the Nile Delta aquifer in Cairo, with increased salinity up to 2000 ppm compared with the present situation in both scenarios of sea level rise. The salinity of groundwater in the northern portion of coastal aquifer will be increased by 10,000 and 18,000 ppm for the sea level rise scenarios of 50 and 100 cm, respectively. However, in both scenarios the deep layers of the aquifer which contain saline and brine water will be diluted by sea water.

Keywords: Nile Delta aquifer; Sea water intrusion modelling; SEAWAT; Climate change, Egypt.

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DETERMINING SUITABLE DROUGHT MONITORING INDEXES AND DEVELOPING A MIXED METHOD

(Case Study, Ardabil Province, North-West of Iran)

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ABSTRACT

The objective of this study was to determine suitable drought monitoring indexes using the approach of systematic simulation and evaluation of interactions between water resources and historical drought in a region and to develop a mixed method. One of the important and efficient tools in drought monitoring systems is monitoring indexes, which in the case of compatibility with the conditions of application environment has a considerable effect on monitoring, pre-warning and often predicting this phenomenon. This is only possible if the mentioned indexes are selected based on the need and conditions of the application location. In this research, the studied region was Ardabil province in north-west of Iran and the objective was to determine severity and range of drought in the region. Three indexes were utilized for monitoring drought: PNPI (Percent of Normal Precipitation Index), DPI (Deciles Precipitation Index) and SPI (Standardized Precipitation Index). Information of 10 stations in the study area were used. The results showed that SPI clearly indicated drought condition in Ardabil province in 3 and 6 month scales since, in the selected dry years, values of this index illustratively decreased to the under-normal value. Oscillation trend of SPI corresponded to hydrologic oscillations in snowy regions in 6 months scale and, in farther regions, it was in 3 months scale. Through constant use and monthly analysis of SPI values in 3 and 6 months periods, reliability coefficient of this index could be increased and validated and also a kind of 3 to 6 months pre-warning system could be obtained prior to the drought.

Keywords: Drought indexes, Drought monitoring, SPI, Agricultural drought, Probability distribution, Ardabil province, Iran.

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TIDAL LOWLAND AND A MICRO TIDAL HYDRO-POWER DEVELOPMENT RELATED TO FOOD CROPS SECURITY IN PAPUA, INDONESIA

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ABSTRACT

Since the beginning of the last century, Buginese, Banjarese and Malays have reclaimed the coastal strips of Indonesia, mainly for agricultural purposes and to cope with the soil and water management problems. With their "long-established" techniques approximately 2 million ha of land have been reclaimed along the Eastern coast of Sumatra (Riau, Jambi, South Sumatra and Lampung provinces) and along the Western and Southern coast of Kalimantan. Since the last few years, the Indonesian Government has started to discuss the possibility to develop Papua as the central production of agriculture, mainly for food crops. Papua Province, called Irian Jaya prior to 2002, is the largest and the easternmost province of Indonesia.

Based on the preliminary survey and investigation, it was estimated that the area suitable for agricultural development was about 1.2 million ha and the development focused on the Southern part of Papua (Merauke and surrounding).

Out of 530,000 ha between Merauke River and Bian River, merely13% is suitable for tidal irrigated rice, dry land crops 6%, supplemented irrigated rice 53% and upland crops 28%.

Mini tidal hydro-power generation has a potential in the area in order to support development. The estimated energy of about 10,000 kwh/month can be generated for a basin of 10 ha, for a tidal range of 4 m during spring tides and 2.4 m during neap tides. This energy may serve about 200 households or 400 ha of agricultural land.

Land suitability analysis and environmental consideration have to be carried out carefully for the lowland around Merauke (southern coast) of Papua to support the food crops and energy security programme of Indonesian Government in a sustainable way. Besides, a zonation system is recommended to optimize the land use planning within this area.

Keywords: Lowland development, soil and water management strategy, food crops security, zonation system, mathematical modelling, energy security, tidal hydro-power.

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GREEN GROWTH BY UTILISING WATER RESOURCES EFFICIENTLY AND ACCURATELY

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ABSTRACT

GAP Organic Agriculture Cluster Project (GAP Organic) is being implemented by the Southeast Anatolia Project Regional Development Administration (GAP RDA) with the technical assistance of the United Nations Development Programme (UNDP). The Project aims at improving the competitiveness of the organic agriculture sector in GAP region and hence contributing to the development of the Region in a sustainable and equitable manner. The project is implemented by Eğil Organic Food Grains Producers Union with the financial support by Every Drop Matters (EDM), a partnership between the United Nations Development Programme (UNDP) and The Coca-Cola Company. Name of Project is Green Growth by Utilising Water Resources Efficiently and Accurately. The project is located at Ilgın village and around, Eğil District-Diyarbakır Province in Turkey. The project period is from March 2015-November 2016. This project aims to enhance the irrigation capacity of 35 organic farmers. As a result of this project, the farmers will be able to diversify their agricultural activities, even with the current water scarcity by growing fruits and vegetable. These activities will also encourage and motivate rest of the 200 union members who live in surrounding towns.

Key components of the activities will include;

1. Construction of 600 m^3 irrigation pool
2. Channeling of water from irrigation pool to individual farming lands
3. Capacity development activities in irrigation and effective utilisation of water to 235 farmers (consisting of all union members) and their spouses (total of 470 people).

Keywords: Sustainable development, organic agriculture, modern irrigation, pilot projects.

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INVESTIGATING CLIMATE CHANGE IMPACTS ON SURFACE SOIL PROFILE TEMPERATURE (CASE STUDY: AHWAZ – SW OF IRAN)

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ABSTRACT

In arid and semi-arid regions, warming of soil surface sets in a high thermal gradient which causes intense moisture flow. In recent years, researchers have noticed ascending trend of temperature at watershed level. The present study proved the occurrence of ascending trend in time series of temperature through both non-parametric and Mann Kendall parametric tests as well as linear regression in synoptic station in Ahwaz province, Iran. While the degree of trend was determined, the relations of Soil-Medium temperature were obtained for the depths of 5 and 30 cm. Applying the relations of ascending air temperature with the relations of soil-medium temperature, a new relation was developed which can express the ascending trend of soil temperature based on medium temperature. These relations indicated that, at depths of 5 and 30 cm, the soil temperature is higher, respectively, by 2 and 1 ˚C than medium temperature. Furthermore, the ascending trend of temperature gradient of soil surface profile in depths of 5 and 30 cm is respectively 0.038 and 0.030 ˚C per year. Although the increase of soil temperature is small, these low soil temperature changes are effective on plant growth and soil properties like moisture profile of soil structure alteration, thermal conductivity, heat capacity and heat diffusion coefficient.

Keywords: Climate Change; Medium Temperature; Soil Temperature; Time series; Trend.

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REGIONAL DROUGHT MONITORING IN AGRICULTURE WITH REMOTE SENSING

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ABSTRACT

The World Meteorological Organization (WMO) and Global Water Partnership (GWP) have launched an Integrated Drought Management Programme (IDMP) to improve monitoring and prevention of droughts. In the frame of this project this study focuses on identification of agricultural drought characteristics and elaborates a monitoring method (with application of remote sensing data), which could result in early warning of droughts before irreversible yield loss and/or quality degradation occur. The spatial decision supporting system to be developed will help the farmers in reducing drought risk of the different regions by plant specific calibrated drought indexes.

The study area was the Tisza River Basin in Central Europe within the Carpathian Basin. For the investigations, NDVI was calculated from 16-day moving average chlorophyll intensity and biomass quantity data. We statistically normalized the crop yield maps and the MODIS satellite data. Then the drought-induced crop yield loss values were classified. The crop yield loss data were validated against the regional meteorological drought index values (SPI), the water management and soil physical data. The objective was to determine the congruency between the spectral data and field measurements. As a result, five drought risk levels were developed to identify the effect of drought on yields: Watch, Early Warning, Warning, Alert and Catastrophe. In this study the impact of drought on wheat and maize price, concrete programming of a user friendly drought monitoring and yield loss mapping process and possible integration practices of drought monitoring and yield loss forecasting method were developed and assessed. The remote sensing based Agricultural Drought Monitoring and Yield Loss Forecasting Method can effectively indicate anomaly of droughts and yield losses and can identify the possible intervention areas. The methodology is also appropriate for early warning of droughts, since yield loss can be predicted 2 months before the irreversible yield loss and/or quality degradation realized in the case of wheat and maize. By plant specific calibrated yield loss maps the developed spatial decision supporting system gives precise information for farmers on drought risk of the different region. The results offer concrete identification of remote sensing and GIS data tools for agricultural drought monitoring and forecast, which eventually provides information on physical implementation of drought risk levels.

Keywords: Biomass monitoring, Drought effects and risks, Normalized difference vegetation index (NDVI), Remote sensing, River basin.

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CLIMATE CHANGE IMPACTS ON FOOD SECURITY IN LOWER MEKONG BASIN

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ABSTRACT

The Mekong River in Southeast Asia is among the greatest rivers in the world. The Lower Mekong Basin (LMB) covers an area within Cambodia, Lao PDR, Thailand, and Viet Nam. Agriculture is the single most important economic activity in the LMB. The livelihoods and food security of most of the basin rural inhabitants are closely linked to the Mekong River and its waterway. Climate change in the LMB is expected to result in an increase in the frequency and severity of floods, droughts, and saltwater intrusion. Such changes are expected to affect natural ecosystems, agriculture and food production, and also exacerbate the problems associated with supplying the region's increased demand for food. Mekong River Commission (MRC) has implemented a study to facilitate the long-term planning and policy-making in the crop production sector towards a food secured and poverty-alleviated future for the LMB under the climate change. Rice yield for Northeast Thailand was simulated by using the ecology specific data under the SWAT (soil and Water Assessment Tool) model. The result of the SWAT model showed the reduction of rice yield 9-24 percent in 2020-2029, 20-30 percent in 2050-2059, and 31-32 percent in 2080-2089. However, for the long-term insecurity, risks and vulnerabilities other than the direct impact of climate change on rice yield, also need further investigation.

Keywords: Mekong River, Climate Change, Food Security, SWAT model, Regional Water Management.

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PERFORMANCE REVIEW AND POLICY OPTIONS FOR SUSTAINABLE IRRIGATION DEVELOPMENT IN LAO PDR

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ABSTRACT

Over the past two decades, irrigation has been a vital and integral part of agricultural and rural development programs throughout Lao PDR. Areas under irrigation have more than tripled from 0.15 million ha (Mha) in 1991 to 0.46 MhA in 2014. Unlike many other parts of Asia, the irrigation potential of the country has yet to be fully realized, with adequate land and water for expansion and intensification in most provinces. Continued investments in irrigated agriculture are forecast in coming years, as reflected in the current (8th) National Socio-Economic Development Plan for 2016-2020 and related high level policies and plans.

The plans are ambitious, but also recognize the major challenges that constrain irrigation system management. Field observations and assessments are revealing mixed performance and a host of technical, economic, institutional and environmental issues are as yet unaddressed. There is a shared understanding that sustainable irrigation development and management implies intervention and guidance in, at least, four specific areas: i) improving market orientation and opportunities; ii) climate change adaption through improved water management; iii) informal private irrigation; and iv) eco-system services protection and tradeoffs. These, and other areas, need careful consideration to support policy recommendations on the future development of the irrigated agriculture sector and related support services in Lao PDR.

Keywords: Irrigation schemes, Public policy, Participatory irrigation management; Ecosystems, Climate change adaption, Lao PDR.

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SIMULATING TEN DAY EVAPOTRANSPIRATION ESTIMATES AT A SPATIAL SCALE OF 60M BY DISAGGREGATING FREELY AVAILABLE MODIS LST AND NDVI PRODUCTS

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ABSTRACT

Accurate assessment and mapping of actual evapotranspiration (ET) on finer temporal and spatial scales is of greater significance in various aspects of agricultural water management. Usage of remote sensing based monitoring of ET is advantageous over ground based measurements as the latter provides point values and won't address the uncertainty arising due to heterogeneity. Remote sensing based ET algorithms are based on energy balance models. In tropical regions such as India, there are two major challenges faced in this regard: acquisition of cloud-free satellite images during the monsoon seasons and coarser resolution of the available thermal bands. Disaggregation of Land Surface Temperature (LST) and Normalized Vegetation Difference Index (NDVI), the key inputs to the energy balance model are needed at higher temporal and spatial resolutions at the length scales defining field boundaries, to improve the accuracy of ET estimates. In this study, DisNDVI algorithm (Bindhu et al., 2015) was modified to better represent the field level variations arising due to differences in sowing and transplanting dates, irrigation and nutrient management. Polynomial fits of the nearest coarser resolution homogeneous agriculture pixel derived from MODIS NDVI composites were used in disaggregation. Further, the present study employs a modified NL-DisTrad (Bindhu et al., 2013) algorithm to disaggregate MODIS 1km LST products by making use of even partial cloud free LST images identified from MODIS 16 day NDVI composites. It has to be noted that it is difficult to get frequent cloud-free daily images during the monsoon and hence NDVI composites and partially cloud-free daily LST images were used to get finer resolution partial LST images at more frequent time scales within the growing season. These disaggregated NDVI and LST images were then used as input for a modified single source energy balance algorithm. The resulting ET at 60m and 240m when compared with the LANDSAT 8 derived ET showed that the ET simulated at 60m is more accurate as it corresponds to the length scales defining the field boundaries in India.

Keywords: Spatial and temporal disaggregation, Evapotranspiration, Remote Sensing, Land Surface Temperature, NDVI, Energy balance.

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INTERNATIONAL WATER TRANSFER PROJECT: NORTHERN CYPRUS TURKISH REPUBLIC WATER SUPPLY PROJECT (TRNC)

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ABSTRACT

The Turkish Republic of Northern Cyprus (TRNC), like most other islands, have problems of fresh water shortage. Because of irregular rain distribution, rain pour down to the Mediterranean Sea directly without infiltration and due to climate change and high temperature, evaporation is increasing in water storage structures. To face the water shortage, groundwater is overexploited causing a decline of the water table below the sea level. This made island water salty and so TRNC has one of the lowest domestic water quality in the world.

Turkey Government implemented an under-sea Water Supply Project which is achieved for the first time in the world, to solve the problem of water shortage in TRNC. The project aims to transfer about 75 million cubic meter (MCM) water per year (2.38 m^3/s) from Turkey through an 80 km long pipeline. By this project, 37,24 MCM water per year will be transferred for irrigation, 37,76 MCM water per year will be transferred for domestic purposes from Turkey. All dams and pipeline in Mediterranean Sea are completed in 2015.

This project, which is an important international experience in terms of water transfer under sea level, will be an example to other countries which have problems of water shortage.

Keywords: TRNC Water Supply Project, water shortage, water transfer, dams, irrigation and drainage systems, water and food security.

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ANALYSIS PRECIPITATION AND TEMPERATURE ANOMALY: CLIMATE VARIABILITY AND CHANGE IN THE PAST AND FUTURE IN SOUTHWEST OF IRAN

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ABSTRACT

Climate change is a fundamental threat to global food security considering the complex role agriculture plays in social and economic systems. Therefore, changes in hydroclimate variables in face of climate variability and change should be analyzed for impact studies. This paper aims at determining the range of natural variability for a case study, Karoun river basin in the South Western Iran. Changes in both precipitation and temperature anomalies in face of future climate change under two scenarios of A2 and A1B are also studied based on sixteen General Circulation Model outputs. 1000 year control run of CGCM3 is used to study the range of natural variability at first step. Analysis suggests that with 95% probability,±40%variation in precipitation and ±0.62 degree Celsius in temperature can be considered as natural climate variability range of the region. These results are obtained based on plotting two-variant normal distributions of precipitation and temperature for five stations. Moreover, it has been expected that an increase beyond the range of internal variability is likely for future (2015-2044) projection of temperature anomalies with respect to 30-year base-line under A2 and A1B scenarios whereas changes in precipitation anomalies (in percent) are almost within the range of natural climate variability.Understanding regional climate variability and change are important for all sectors for planning and mangemnetproviding useful insights to policymakers for future adaptation strategies.

Keywords: Precipitation and temperature anomalies, Climate Change, AOGCMs, Karoun basin- Iran.

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AGRICULTURAL WATER MANAGEMENT SYSTEMS IN THE KHANDESH REGION OF MAHARASHTRA STATE, INDIA

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ABSTRACT

Irrigation water management is an interdisciplinary, multi system science, which was historically developed on a participatory mode. Some of these systems are so old that it is impossible to establish their antiquity. At a later stage, more emphasis was given on creation of physical structures like dams, canals and other on-farm structures. The socio-cultural, organizational and economic aspects of irrigation development were overlooked, resulting in lower performance of such irrigation projects. In this paper an attempt is made to study traditional community managed block irrigation system, popularly known as Phad irrigation system, from the Khandesh region of the Maharashtra State, India. Phad (block) irrigation system of the Maharashtra State is one of oldest community managed irrigation systems in India. These irrigation systems have relevance even today for providing predictable, reliable and equitable water to farming community. Crop rotation, irrigation management by community participation and involvement of farming community etc. are some of the unique features of these irrigation systems. But now this age-old water management system is under threat due to changed environment. However, small farmers can organize themselves and have such systems in small and medium irrigation projects viz. Waghad irrigation project of Maharashtra, India. There is scope to have Phad (Block) irrigation system in this and similar other projects. Also in Kolhapur and Sangli District of Maharashtra there are number of private and co-operative lift irrigation schemes, where farmers are organized. In these schemes also there is scope to have Phad (Block) irrigation system.

Keywords: Community managed irrigation, Phad irrigation system, Regional water management, Participatory irrigation management.

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INTEGRATED WATER MANAGEMENT FOR THE NATIONAL CAPITAL REGION OF DELHI

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ABSTRACT

The National Capital Region (NCR) of Delhi is endowed with perennial rivers namely the Yamuna, Hindon and Kali passing through it and the Ganga skirting its eastern boundary. While the U.P. Sub-region has abundant ground water, the area west of river Yamuna comprising the districts of Gurgaon, Rohtak, Sonipat, Jhajjar and most part of Faridabad district in Haryana, Alwar in Rajasthan and large parts of NCT-Delhi have insufficient ground water, which is often brackish in quality rendering it unpalatable for domestic consumption. NCR draws its water needs from the Yamuna, Western Yamuna canal, Upper Ganga canal system and partly from ground water (ranney wells in Yamuna belt and tube wells).

It is a water scarce region and due to heavy withdrawal of ground water, ground water levels have declined in most parts of NCR. With the growing population, depleting ground and surface water resources in the region, meeting the demand of water for various uses such as drinking, industrial and irrigation is a big challenge. There is generally a wide demand-supply gap of water in NCR and the problem becomes acute in dry summer months. A holistic view of the water demand and supply in the NCR region is required to be taken for the Integrated Water Management taking the regional approach. Also the losses in the various stages of the water supply system needs to be assessed and rectified to a reasonable limit to save valuable water from going waste.

The paper examines all the potential surface water sources, ground water aquifers, inter basin transfer of water, demand supply gap, leakages in the existing supply systems, etc. as well as demand and suggests mechanism for improving the water supply scenario in the region. It proposes the need for sound assessment and effective management of available water resources in the region for sustained use and equitable distribution to the entire region through a techno–economic & comprehensive conveyance system linking water surplus area with water–deficit regions. It will propose the possible policies which will address the demand management as well as supply management related to all the broad uses of water in the region.

Keywords: NCR, demand supply gap, equitable distribution, integrated water management.

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Papers Presented Under

SUB-THEME 3
Key and smart actions to alleviate hunger and poverty through irrigation and drainage

Topics

3.1 Water and climate smart approaches for sustainable smallholder agriculture

3.2 Financing mechanisms for development and management of irrigation and drainage projects

3.3 Adaptation measures for rural water management for water and food security


Sub-theme 3

RAISING WATER PRODUCTIVITY LEVELS AND ENSURING SUSTAINABILITY OF IRRIGATION FOR HIGH WATER USING CROPS

Oner Cetin[1], and Nese Uzen[1]

ABSTRACT

Increasing water demand for industrial and domestic use and for environmental sustainability entails efficient water use in agriculture. On the other hand, irrigation can maximize the crop yield and/or irrigation water use efficiency (IWUE) or water productivity and maximize the farmer's economic returns. Improving water use efficiency or enhancing water productivity in a sustainable manner is crucial to irrigated agriculture and water use. In this study, yields of the crops, IWUE or irrigation water productivity, net returns per unit land area and per unit of water used for some higher water-using crops (cotton, corn, sugar beet, tomatoes and winter wheat) in Turkey were computed and discussed vis-a-vis different amount of irrigation water, irrigation methods and some different climatological regions. According to this study, net return per unit land area and per unit water in the different regions of Turkey were $ 430-6707/ha and $ 0.10-1.22/m^3 depending on different crops and region, respectively. Water cost also varied from $ 0.05/m^3 through $ 0.20 /m^3 depending on the regions. These figures showed that irrigation water has not been used with the same efficiency in different regions of Turkey. Meanwhile, having the highest water use efficiency does not mean that net returns will be highest for all the crops. The most profitable use of water is somewhere between the amount that provides highest water use efficiency and the amount that provides for maximum yield. Water productivity and/or net return for farmers could be, thus, increased using micro irrigation and appropriate irrigation schedules. Irrigation scheduling ensured higher water prodcutivity is, thus, important in view of the global scale of fresh water crisis. However, ensuring sustainability is closely dependent on other inputs such as nitrogen, crop variety, agronomic practices, climate conditions etc. In this article, irrigation schedules and regimes on higher water productivity and the approaches towards achieving sustainability for higher water-using crops are also discussed.

Keywords: Water productivity, Sustainability, Net return, Irrigation water use efficiency (IWUE).

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EVALUATION OF DRIP IRRIGATION AND FERTIGATION LEVELS IN AEROBIC RICE FOR HIGHER WATER PRODUCTIVITY

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ABSTRACT

A field study was conducted to evaluate the potential of surface drip under variable climate based schedules and N-fertigation levels on growth and yield of aerobic rice in semi-arid region of India.The experiment was conducted for three years (*kharif* 2012, 2013 and 2014) in split plot design with 3 replications at Water Technology Centre, College of Agriculture, Prof. Jayashankar Telangana State Agricultural University (PJTSAU), Hyderabad, India.The main treatments consisting of 3 drip irrigation schedules (at 100,150 and 200 % pan evaporation replenishment) and the sub-treatments comprises of four N fertigation levels (0,60,120,180 kg N/ha). Drip irrigation scheduling and N-fertigation levels significantly affected the rice grain yields in *kharif,* 2012 and 2013 seasons. Whereas, during *kharif,* 2014 nitrogen fertigation levels only significantly influenced the grain yield of aerobic rice. Irrigation equivalent to 150% pan evaporation replenishment produced significantly higher grain yield over 100% pan evaporation replenishment. Each higher level of nitrogen significantly enhanced the grain yield of rice up to 120 kg N/ha. The seasonal water use (ETc) in drip irrigated aerobic rice ranged from 729 to 979, 617 to 1108 and 504 to 1008 mm in *kharif*, 2012,2013 and 2014, respectively under different drip irrigation schedules with mean water productivity values ranges between 0.35 to 0.49 kg m^{-3} among drip irrigation regimes.

Keywords: Climate change, Aerobic rice, Drip irrigation, Fertigation, Water productivity.

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DEMAND-SIDE WATER MANAGEMENT IN SUGARCANE FARMING IN INDIA THROUGH FARMERS' BEHAVIOUR CHANGE: EXPERIENCE FROM DSCLSUGAR AND OLAM

Richard Colback[1], Harsh Vivek[2], and Suparna Jain [3]

ABSTRACT

Sugarcane is a prime commodity in agribusiness in India, which is the second largest producer of sugarcane in the world after Brazil. It supports livelihoods and offers the potential for export at globally competitive prices. Over 50 million farmers are engaged in sugarcane cultivation on over four million hectares of land, in addition to over 20 million more individuals who depend on employment generated by the sugar mills and other industries related to use of this sugar. In a resource constrained market such as India, there is an increasing need to promote resource use efficiencies that will avoid competing claims over the limited agricultural land and water available. Improvements in water management through a demand side approach have been identified within this project as a way to bridge the resource availability and sustainability gap. In an attempt to avoid conflicts that have arisen in Indian States such as Maharashtra, wherein concerns related to diversion of water for irrigation had been exacerbated by sudden and erratic drought like conditions, the project demonstrated efficiencies that could be gained from low cost interventions. The project was guided by the '3S' principle of Suitability, Sustainability and Scalability. The project took into consideration agro-climatic and soil conditions, and identified low cost water efficient techniques for promotion such as: trash mulching; use of organic manure; furrow irrigation; drip irrigation; land levelling; and gated pipes. As a result of the efforts made with 100,000 sugarcane farmers, approximately 64 billion litres of water-use for irrigation has been avoided through the use of improved water management practices. The variability of water efficiencies gained from the different practice interventions were also computed duringa12 month data recording on demonstration plots within the project. The value proposition of the project activities was found to be multifaceted, including catalysing farmers' behaviour" towards demand side water management which led to greater efficiencies (more crop per unit water), as well as managing supply-chain and business risks emerging from impending water challenges to provide a clear business case for water efficiency practices and investments in equipment to larger organizations such as sugar mills and financial institutions.

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CLIMATE SMART LAND AND WATER MANAGEMENT FOR SUSTAINABLE AGRICULTURE

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ABSTRACT

The Coupled Model Inter-comparison Project Phase 5 (CMIP5) based model ensemble, projects a warming of 1.5, 2.4, 2.8 and 4.3 °C for India under the RCP2.6, RCP4.5, RCP6.0 and RCP8.5 scenarios, respectively, for 2080s (2071-2100) compared to the baseline period of 1961-1990. The all-India precipitation is projected to increase by 6, 10, 9, and 14% during 2080s under the above scenarios, respectively. The Indian Council of Agricultural Research (ICAR) through its network project on National Innovations on Climate Resilient Agriculture (NICRA) has demonstrated different land and water management interventions in the vulnerable districts of India to enhance resilience of agriculture to climate change and climate variability. Rain water harvesting and its judicious utilization through farm ponds and community tanks in rainfed districts of Bihar, Maharashtra, Rajasthan and Telangana states demonstrated the ability to meet critical irrigation requirements and also enhance the cropping intensity (20 to 135%), and a change in the cropping practice to vegetable cultivation with micro-irrigation systems. Construction of temporary check dams (*boribandhan*) in high rainfall areas in the states of Jharkhand, Maharashtra, Madhya Pradesh brought low land areas into cultivation which otherwise remained fallow due to inundation in *kharif* (*monsoon*) season. This intervention lead to supplemental irrigation facility and also recharged open wells in the nearby area. The storage created through these interventions (about 55000 m^3) benefitted 86 farmers and increased cropping intensity to 100% in Datia district (Madhya Pradesh). Renovation of *Aahar* (water reservoir) and construction of farm ponds in Bihar helped in providing protective irrigation to 24 ha during dry spells in *kharif,* increasing paddy productivity by 20.7% and also raised the ground water level by 30 cm. Similar interventions in West Godavari reduced the flood inundated area during Neelam Cyclone, saving yield loss of 2.6 to 4.1 t/ ha of various paddy varieties. Some of the promising climate smart practices are being mainstreamed into the National Mission for Sustainable Agriculture (NMSA) for out-scaling.

Keywords: Climate Change, NICRA, Technology Demonstration Component, NMSA, *Bori Bandhan*, *Aahar and Pynes*.

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PERFORMANCE OF SURFACE AND SUBSURFACE DRIP FERTIGATION ON YIELD AND WATER USE EFFICIENY OF SUGARCANE

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ABSTRACT

The present investigation was taken up with an aim to assess the effects of surface and subsurface drip fertigation with Water Soluble Fertilizer (WSF) and Normal Fertilizers (NF) for maximizing the cane productivity and water use efficiency of sugarcane. WSF and NF were tried at two doses *viz.,* 100 and 75% of RDF and also in combination with WSF and NF (75%WSF+25%NF, 50WSF+50%NF and 25%WSF and 75%NF) by subsurface drip fertigation and 100% RDF by surface drip fertigation. These were compared to surface drip fertigation with 100 RDF with WSF and NF and surface irrigation and soil application of NF at 100% RDF. Chipbud seedlings were planted with Paired row with triangular (Zig Zag pattern) planting (40/125 x 45 cm). Imported water soluble fertilizers *viz.,* Mono Ammonium Phosphate (12:61:00), Polyfeed (19:19:19), Potassium Nitrate (13:00:45) and Urea (46:00:00) were tried under surface and subsurface drip fertigation. Both surface and subsurface drip irrigation were scheduled based on crop evapotranspiration (ETc) once in two days. Fertigation was scheduled once in seven days with different forms of fertilizer grades. The experiment was laid out in a randomized block design with three replications of sugarcane raised under surface and subsurface drip fertigation. Results from the investigation showed that sugarcane responded well to different forms of fertilizers grades and fertigation regimes on yield and water use efficiency of sugarcane under both surface and subsurface drip fertigation. The result revealed that considerable saving of irrigation water was noticed under both SSDI (30.73%) and SDI (22.70%) over surface irrigation. This revealed that adoption of SSDI has resulted 8-9% additional water saving compared to SDI. Increased water use efficiency (WUE) was registered with SSDI over to SDI and surface irrigation. Among SSDF, SDF and surface irrigation with soil application of NF, SSDF has recorded higher WUE (1.52 t ha. cm-1) compared to SDF (1.23 t ha. cm-1) at 100% RDF with WSF and surface irrigation with soil application of 100% RDF with NF (0.53 t ha. cm-1). The increase in WUE was to the tune of 2.75 to 2.86 times higher under SSDF and 2.23 times higher under SDF at 100% RDF with WSF compared to surface irrigation with soil application of NF at 100% RDF. The result of present study clearly indicated that SSDF has achieved an additional WUE of 23% over SDF. In terms of sugarcane productivity, maximum cane yield of 193.94 tonnes per hectare was achieved by SSDF at 100% RDF with WSF which was 10.51 and 89.63 per cent over than SDF at 100% RDF with WSF (175.14 tonnes per hectare) and surface irrigation with soil application of NF at 100% RDF (98.38 tonnes per hectare) respectively. It was concluded that subsurface drip fertigation with WSF at 100% RDF in Sugarcane (chipbud seedlings planting) has resulted higher water saving, cane yield and water use efficiency.

Keywords: Surface Drip fertigation, Subsurface Drip fertigation, Cane yield, Water saving, Water use efficiency.

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AN OPTIMIZED, REAL TIME DECISION SUPPORT SYSTEM FOR BASIN SCALE IRRIGATION SCHEDULING

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ABSTRACT

The Murrumbidgee in Australia conveys water from headwater storages downstream for irrigation, municipal and environmental purposes. The daily management of the river is a complex task that needs to take into account not only the demands of irrigators and other water users but also a range of catchment and river processes that are difficult to quantify. This often results in water being released from headwater storages which are surplus to the actual requirements.

Water NSW is the bulk water delivery operator for all rural rivers in the State of New South Wales. As part of a major upgrade of the river management and operational practices for the Murrumbidgee River, a Computer Aided River Management (CARM) decision support system has been developed and implemented.

The CARM system integrates real time data of meteorological forecasts, pump extraction rates and future irrigator orders, rainfall, river flow and level data as well as control structure releases and gate settings. The system combines such data with a suite of hydrological, hydrodynamic and integrated catchment models to provide forecasts of future river inflows and automatic updates of the model state so that it continuously emulates the real river behaviour. An optimization process further enables the system to provide future operation instructions for the dams and regulation structures for all operating conditions including scheduled irrigation operations, environmental releases and dam storage operations.

The CARM is implemented as a fully integrated Decision Support System (DSS) and includes a range of functionality including a time series database, purpose-built graphical user interface, workflows defined for specific river operations procedures, in-built programs to prepare and extract data and execute external simulation models.

CARM is currently being adopted for real-time management on the Murrumbidgee River, and it is expected that similar systems will be developed in the future to manage all major regulated rivers in the state. The CARM project has been recognized as a game changer in Australian river operations and has won two major national awards for engineering excellence and innovation.

Keywords: River operations, Irrigation scheduling, optimization.

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SENSORS FOR WATER MONITORING FOR IMPROVED ON FARM WATER MANAGEMENT

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ABSTRACT

Sustainability of agriculture is important in the context of Climate Change, soil degradation and scarce water resources. The existing irrigation management practices by farmers are not sufficient in improving water use efficiency and water productivity. The solution may be found in accessing and making use of real time information in water management decisions. The paper presents pilot initiative of WALAMTARI under ClimaAdapt project, on use of smart technology for obtaining real time information and establishing decision support system. Low cost sensors were developed and used in the field area for field channel water flow information and on-farm water and environmental parameters. Technology options for data acquisition, processing and decision support system are identified. For on-farm water monitoring the ultrasonic sensors was used with RBC Flume for water inflows and outflows. For measuring the water in the fields ultrasonic sensors fitted to Bowmen water tube are used. Other parameters measured are temperature and relative humidity. The lessons learnt from the pilot on research, innovation and capacity building activities can together create enabling conditions for change management through policy advocacy and scaling up.

Keywords: Smart Technologies, Low cost sensors, Bowmen water tube, RBC flume.

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EFFECT OF CROP ESTABLISHMENT TECHNIQUES ON MORPHOLOGICAL AND YIELD PARAMETERS IN AEROBICALLY CULTIVATED RICE

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ABSTRACT

Agriculture in Sri Lanka consumes more than 96% of the fresh water in which the share of rice is more than 80%. Normally water requirement for low land rice is about 5-6 feet (1.3-1.5 m) for one season but, more than 50% of this is lost through evaporation, percolation and seepage during land preparation and crop growth. In contrast, aerobic rice cultivation is practiced in well-drained, non-puddled and non-saturated soils with supplementary irrigation. Moisture status is maintained at or near field capacity. Therefore, water productivity is increased by reducing the water losses. Water productivity in aerobic rice farming is reported to be 32-88% higher when compared to lowland rice. Hence, an alternative management option to deal with water shortage for lowland rice cultivation is to raise aerobic rice in lowland fields.

At present, dry seeding before the onset of rainfall is the common seed establishment technique in aerobic rice cultivation. However, it faces uncertain prospect due to unpredictable onset of rainfall. In this research, five crop establishment techniques namely direct dry seeding, direct wet seeding, parachute method, transplanting after one week and transplanting after two weeks were tested with a 2 1/2 month rice variety (BG250) to choose an appropriate crop establishment technique in lowlands. Morphological and yield parameters were monitored and compared among the treatments. Method of establishment affected both, morphological and yield parameters significantly ($p<0.05$). Lowland rice gave significantly better results than aerobic rice that was established through five different techniques, namely direct dry seeding, direct wet seeding, parachute method, transplanting after one week and transplant after two weeks. However, when different establishment techniques were compared, transplanting after one week yielded superior results for all the parameters while direct dry seeding yielded the poorest results. The second desirable was the parachute method and the third was wet seeding of pre germinated seeds. Since transplanting involved intensive labour, parachute method can be considered for crop establishment for aerobic rice in lowland fields.

Keywords: Aerobic rice, Crop establishment techniques, Lowland rice, Morphological parameters, Yield parameters.

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DRIP IRRIGATION UNDER DIFFERENT CLIMATIC CONDITIONS ON SUGARCANE IN CHINA'S GUANGXI PROVINCE

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ABSTRACT

Based on an analysis of the precipitation over the sugarcane-growing areas in the Guangxi Zhuang Autonomous regions under different climatic conditions from 1955 to 2014, the lower limit of soil moisture when irrigation is needed has been set. The paper suggests developing a set of high-efficient and water saving irrigation technologies for sugarcane, which cover the segments from headwaters to farmland. Compared with the traditional irrigation methods, modern technologies for drip irrigation have increased sugarcane yield by 35122 kg/hm^2 and decreased irrigation water by 1125m^3/hm^2; project investment has accordingly reduced by 17%.

Keywords: Different climates; Sugarcane; Sustainable development.

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UNEVEN IRRIGATION AND ECONOMIC INEQUALITIES: EXPLORING THE CONNECTION

Ana Manero[1]

ABSTRACT

Irrigation development is widely recognised as a key instrument to boost livelihoods and food security, particularly in rural developing areas. While improved water supply can help reduce average poverty levels, uneven access to sufficient and reliable irrigation water can also result in aggravated economic disparities. Using a combination of qualitative and quantitative analyses, this article explores the impact that uneven irrigation water supply has on two smallholder irrigation schemes in southern Tanzania. The results reveal that inequality of water supply is a major concern for most irrigators and that farmers who receive inadequate water supply are affected in a number of ways. These include reduced crop yields, greater uncertainty, worsened working conditions, inability to cultivate their own land, higher risk of land turning unproductive and higher financial losses. While Tanzania's water and irrigation national legislation mandates equity of water supply, the problem persists within smallholder systems due to a complex combination of issues, including inability to measure water supplies, poor infrastructure maintenance and lack of adequate regulations at local levels.

Keywords: Crop yields, Irrigation schemes, Poverty, Economic inequality, Tanzania, Water distribution.

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SCALE EFFECT OF WATER SAVING IN A RICE-BASED IRRIGATION SYSTEM IN SANJIANG PLAIN, NORTHEAST CHINA

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ABSTRACT

Water budget under different surface irrigation water supply ratios and water saving measures was simulated by a semi-distributed water balance model, which was built for a rice-based irrigation district (BLH Basin) in Sanjiang Plain, Northeast China. PF_{nws} and PF_{gws} were defined the ratios of rice evapotransipiration to net water supply and gross water supply, respectively. Gross water supply meant the total amount of irrigation and precipitation and net water supply denoted gross water supply minus the amount of water reused. PF_{nws} were quantified across seven spatial scales and compared with PF_{gws} at Irrigation Scheme Scale. Results showed: (1) PFnws all showed improvements compared with PF_{gws} under 15 kinds of scenarios, average by 29.42% and maximum by 39.88% at Irrigation Scheme Scale. Differences between PF_{nws} and PF_{gws} had a closely positive correlation with the amount of water reused.(2) Water saving irrigation regime (WSIR) had a significant water saving effect (WSE) at Scale 1 (Field Scale). When high intensity WSIR was adopted, PF_{nws} could be improved by 21.2% at Scale 1 (Field Scale).WSE at other scales except Field Scale increased as surface water supply ratio (SWSR) increased, but still less than that at Field Scale.(3) When branch canal water delivery coefficient was raised from 0.65 to 0.80 by canal lining, WSE from Scale 3 (4771.52ha) to Scale 5 (4.29×10^4ha) was slightly larger than that at the other scales. SWSR increase had a positive influence ,while WSIR had a negative effect on WSE of canal lining.(4)When SWSR decreased from 0.4 to 0.3, PFnws from Scale 3 (4771.52 ha) to Scale 7 (Irrigation Scheme Scale) would be improved .Furthermore, SWSR decreased from 0.3 to 0, PF_{nws} remained approximately unchanged at Field Scale and Irrigation Scheme Scale.

Keywords: Rice, Water saving, Water use efficiency, Scale effect.

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CAPACITY BUILDING OF IRRIGATION ASSOCIATION AND IRRIGATION WATER REQUIREMENTS FOR PADDY IN TAIWAN

Sheng-Feng Kuo[1], and Chih-Hung Tan[2]

ABSTRACT

Nearly all the irrigation facilities in Taiwan are operated and managed by the farmers' water users organizations or commonly known as Irrigation Associaitons (IAs), under the government supervision. At present, there are 17 IAs to serve a total area of 375,125 ha farm lands which were owned and or cultivated by 1,528,330 IA members. In addition, there is a Taiwan Joint Irrigation Association (TJIA) aiming to coordinate the activities of all the IAs. A rotational system of water adopts rotation distributions to groups of farmlands in equitable quantity at pre-determined time and in proper order for crop cultivation in Taiwan. Experiments in Taiwan indicate that rotational irrigation can achieve water savings of about 20~30 percent without any sacrifice to rice yield. Water so saved can be used to fully or partially supply irrigation water to areas where there is a complete or partial shortage of water. Since the rotational irrigation practice was initiated in 1956, the productions of more than 126,000 hectares of paddy fields have been improved.

Field experiment for paddy fields with four irrigation methods and two repeat treatments were executed in the Hsueh Chia Experiment Station of Chia Nan IA. The results demonstrated that the irrigation water requirements for farmer method, 7 day, 10 day and 15 day irrigation schedule methods are 1248 mm, 993 mm, 848 mm and 718 mm, respectively. Based on the 7 day irrigation schedule, the percentage of irrigation water requirements for compare method, 7 day, 10 day and 15 day irrigation schedule methods are 125.7%, 100%, 85.4% and 72.4%, respectively. Compare to traditional irrigation methods with 7 day irrigation interval, the alternative wetting and drying irrigation schedules with 10 days and 15 days irrigation intervals can save 14.6% and 27.3% irrigation water requirements; on the other hand, the crop yields will decrease 7% and 15 %, respectively.

The CROPWAT model was used to simulate on-farm water balance with 10 day irrigation schedule for 2nd paddy field in ChiaNan Irrigation Association, Taiwan. The results demonstrated that the total irrigation water requirements, net irrigation water requirements, runoff and infiltration were 1168.6 mm, 818 mm, 187.6 mm and 482.5 mm, respectively. Compare the net irrigation water requirements with 10 days irrigation schedule for paddy field, the results from model and field experiment are 818 mm and 848 mm, respectively and error percentage is 3.54%.

Keywords: Irrigation Association, Capacity Building, Field Experiment, Irrigation Water Requirement, Rotation Irrigation, Paddy.

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WATER USER ASSOCIATIONS FOR IMPROVED AGRICULTURAL PRODUCTIVITY IN TAJIKISTAN: OPPORTUNITIES AND CHALLENGES

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ABSTRACT

After Tajikistan emerged as an independent country, major land reforms took place. Large collective farms were broken up into smaller (*dekhan*) private farms. This created a vacuum, because there was no provision to manage competing needs of water among private farms. Water user associations were created with the efforts of the government, and several international donors, to manage distribution of water between private farms and to share in maintenance of smaller canals.

In this paper we provide a brief description of the creation of water user associations, as well as their roles and responsibilities. We then describe the opportunities for increasing livelihoods, and contributing to increased agricultural productivity. Can these WUAs improve access to and distribution of water? Would better irrigations services increase cropping areas? Would yields of cotton improve? Can these be an improvement in crop diversity? We identify the key existing gaps in knowledge that would provide an understanding of the impacts of these associations on wellbeing. We also describe some of the challenges that may limit the efficacy of these associations. Are these institutions likely to be able to cover their operational costs? Can these institutions serve well as cropping decisions change? Are these institutions likely to represent the needs of female farmers? We identify the key factors that need to be examined more closely, that provide an understating of the resilience of these associations.

The answers to these questions would provide important information for policies to support and strengthen water user associations in Tajikistan.

Keywords: Water User Assocciations, Tajikistan, Dekhan, Agricultural productivity.

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WASTEWATER IRRIGATION EFFECT ON RICE YIELDS IN MUSI RIVER COMMAND AREA IN INDIA – A CASE STUDY

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ABSTRACT

With rapidly depleting fresh water resources, waste water is increasingly seen as a supplemental source of irrigation. Hyderabad, one of India's largest cities, disposes large amounts of its waste water (approximately 850 million liters per day) treated and untreated into the Musi River. A field investigation was conducted in command areas of three anicuts out 23 constructed across Musi river viz., Pillaipally, Bhemalingam and Palliwada anicuts in Nalgonda district, Telangana State, India during *kharif*[7], 2011, to study quality of river and groundwater at different locations and yield variations of rice grown with Musi water and groundwater along the Musi River. Samples of canal and ground water along the canal course and in command areas were collected, and also rice yield data was collected by crop cut experiments in selected farmers' fields. The canal water samples were alkaline (98%; pH of 7.5 to 8.83) and groundwater samples were neutral (7-10%) to alkaline (90-93%). Canal and groundwater samples belong to C3 and C4 classes. Sodium adsorption ratio in three canal and ground water samples was low (S1). Chloride content of three canal water samples (3.2 to 44.8 me l^{-1}) and groundwater samples (2 to 40.4 me l^{-1}) were moderate to unsafe. Both canal and groundwater samples were safe with regard to Fe, Mn, Zn, Cr, Co, Ni and Pb but unsafe in Cu and Cd.

Rice yields (*kharif*) varied from 2625 to 7875 kg ha^{-1}, 3500 to 7850 kg ha^{-1} and 1400 to 7000 kg $ha^{-1}$with the mean yield of 5869 kg ha^{-1}, 5650 kg ha^{-1} and 4040 kg ha^{-1} in the command area of Pillaipally, Bheemalingam and Palliwada anicuts, respectively. Rice yield was negatively correlated with pH (r = 0.331) and EC (r = 0.386) of canal water and with EC (r = 0.50) and chlorides (r = 0.342) and Ca+Mg (r = 0.211) of ground water. There is a need to provided fresh water to farmers by means of government investment in water supply.

Keywords: Waste water irrigation, waste water reuse, rice yield, water quality, Musi river, India.

Sub-theme 3

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7 Kharif is the monsoon cultivation season in India.

WATER SAVING POTENTIAL OF SYSTEM OF RICE INTENSIFICATION – RESEARCH FINDINGS IN INDIA AND ITS IMPACT

Mahender Kumar[1], Sudhakara. T. M[2], K. Surekha[3], Ch. Padmavathi[4], and V. Ravindra Babu[5]

ABSTRACT

A field experiment was conducted on a clay loam soil at Indian Institute of Rice Research (IIRR) Rajendranagar, Hyderabad, Telangana State during wet and dry seasons of 2013-14 and 2014-15 to Evaluate irrigation regimes and nitrogen management practices on production potential of rice (Oryza sativa (L.) under mechanized SRI and SRI methods. The treatments consisted of two planting methods (Mechanized system of rice intensification (MSRI) and system of rice intensification (SRI)) as main treatments, three irrigation regimes (saturation, 5 cm irrigation at three and five days after disappearance of ponded water) as sub treatments and four nitrogen management practices (RDN - 100 % through inorganic, RDN - 75 % inorganic and 25 % organic, Leaf Colour Chart (LCC) based nitrogen application and Soil Test Crop Response (STCR) based nitrogen application as sub-sub plots.

SRI recorded significantly superior in terms of root growth characteristics, yield attributes, grain and straw yield over MSRI. Irrigation maintained at saturation level produced significantly higher growth parameters, yield attributes, grain and straw yield which were comparable with irrigation at 3 DADPW. MSRI and SRI performed at par with respect to B: C ratio. Significantly higher gross and net returns were recorded with SRI over MSRI. The total labour saving was 21 - 25 % in MSRI as compared to SRI.

The saving of the water to the extent of 23-30 % accounts to nearly 2340 – 2700 US$ /ha and 1380 – 1740 US$ /ha during wet and dry seasons respectively and thereby reducing production cost especially under water scarce conditions. Further collaborative research studies are useful in SRI and its modifications to mitigate climate change effects (methane emissions) and for enhancing resource conservation and for wide scale adoptability across the country.

Keywords: Methods of crop establishment, water productivity, Rice-rice system, System of Rice Intensification (SRI) and Mechanized System of Rice Intensification.

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TECHNOLOGY SMART APPROACH TO KEEP DRIP IRRIGATION SYSTEMS FUNCTIONAL

Reinders Felix B [1], and Van Niekerk Adriaan S [2]

ABSTRACT

The world's population is projected to reach 8.5 billion by 2030, 9.7 billion by 2050 and as water stress spreads around the globe, finding ways of getting more crop per drop to meet our food needs is among the most urgent of challenges. The first answer to this call is drip irrigation, which delivers water directly to the roots of plants in just the right amounts. It can double or triple water productivity – boosting crop per drop – and it appears to be taking off worldwide. Over the last thirty years, the area under drip and other "micro" irrigation methods have risen by more than 1000%, from 1, 03 million hectares in 1986 to more than 11 million hectares at present.

Keywords: Drip irrigation, Micro irrigation, Water productivity.

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ARTIFICIAL INTELLIGENCE LEADING TO ANLOW-COST IRRIGATION MANAGEMENT SYSTEM

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ABSTRACT

Management can be defined as the judicious use of the resources to achieve a certain goal. In irrigation, management aims maximizing crop production at the lowest possible cost without compromising the quality of natural resources, using less water and minimizing the water loses. Between management-irrigation techniques, the most used are based on water balance, which consists of determining the amount of water that has been lost to the atmosphere in order to reestablishing it. However, it is necessary to determinate culture evapotranspiration and this requires a weather station close to the site of interest. Analyzing the costs of meteorological stations it is clear that this approach is not feasible for small producers. Even for bigger planters, it requires a professional to calculate hydric balance and to periodically check soil water content. The problem with that is the elapsed time between system changes and correction actions, being the second greater than the first. As many times seen, changes in the frequency of irrigation lead to gains or losses in crop production. For this, a technologically efficient system with reduced cost, easy installation and maintenance is needed. Thus, a network of intelligent sensors, capable of monitoring environment in real-time, adapting to different crop development stages, different soils and crops and to communicating with each other, and to a server becomes an interesting solution to manage an irrigation system. This work aims to elucidate the development of a low-cost wireless sensor/controllers network to determine the soil water content for efficient irrigation management. Electronic modules were developed with low power microcontrollers since they were powered by batteries and solar panels, capable of performing the inference algorithms of the measured variables, calibration and correction of such measures, communication with other network elements and running the irrigation controller, based on Fuzzy Logic. The approach of artificial intelligence that was used has the ability to learn, to estimate parameters from their knowledge base and from the conditions around and to use imprecise data - commonly present in low-cost sensors. In addition to microcontroller capabilities, the sensor module is endowed with elements to measure soil and environmental temperatures, air relative humidity (RH), ambient lighting, soil water content, and with a wireless communication module. With the deployment of this system, an efficient and effective irrigation management can be achieved; and, by system cost, it can easily be accessed by familiar agricultures, as by small and medium farmers. Thus, this system can expand the sustainable use of available water resources and even reduce pollution of soil and water with agrochemicals, leading to the maintenance of future generations.

Keywords: Irrigation management, Fuzzy inference system, Low-cost sensors.

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THE CONCEPTUAL FRAMEWORK OF CLIMATE-SMART IRRIGATION

Michael Davidson[1]

ABSTRACT

Global population is projected to increase by 3 billion over the next 30 years and 80% of this will be in the 49 Least Developed Countries (LDCs). Between 2011 and 2100 the population of high-fertility countries is projected to increase from 1.2 billion to 4.2 billion (UNFPA 2011) and, in that period, agricultural production needs to increase by 70% overall, and by 100% in LDCs (FAO 2009). This challenge is sobering because thye agricultural production in LDCs over the past ten years has been stagnant (Bruinsma 2009). Current paradigms for improving the livelihoods in developing countries have neither reduced poverty in LDCs, nor the level of greenhouse gas emissions from the agricultural sector. It is important to note that while the data for this study are of national scale, there are many regions in the Developed world that have similar quality of life indicator as the LDCs and, conversely, there are farmers and regions in the LDCs who enjoy equivalent quality of life as in the Developed world. Climate Smart Agriculture (CSA) has been developed as a system that answers these challenges. CSA consists of a suite of tools and methods that, when implemented in a sustainable manner and locally supported, leads to the achievement of three basic objectives; *mitigation* of environmental damage caused by traditional agricultural practices; *adaptation* of farming methods and regimes that cope with the uncertainty and variability of climate change; and *food security* or improved agricultural production and profitability for the grower. This paper suggests that the conceptual framework of CSA is important but insufficient to achieve the potential triple win of CSA. The focus of this study is the implementation model for irrigation regimes used by the Development community to achieve the goals of CSA and, in particular, the objective of improving agricultural production. The research identifies gaps in the implementation of irrigation regimes and argues that an associative paradigm, *climate-smart irrigation*, is required to sustainably implement the objectives of CSA. This research identifies one important variable of climate-smart agriculture and illustrates how “set-aside” land due to intensive cultivation is best accomplished by integrated the climate-smart irrigation approach.

Keywords: Climate change, Climate-smart agriculture, Climate-smart irrigation, Agricultural production.

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DESIGN PRINCIPLES AND CONSIDERATION FOR SOLAR POWERED MICRO IRRIGATION SYSTEM

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ABSTRACT

In broad-spectrum micro irrigation is a pressurized irrigation system requires electrical/gasoline powered centrifugal pump-set to generate unswervingly pressure for irrigation of crops mainly for 16-20 hours to meet the crop demand on daily basis. This implies that, while irrigating the crops for 16-20 hours on daily basis, recurring cost of electricity or fuel becomes enormous resulting in non-sustainability and non-viability of agri-irrigation projects. Second important issue is shortage of power. Demand vs supply ratio of power is so truncated every year, that none of the Government is enduring to overcome this ratio in future in spite of allocation of huge funds. UN report says that there is a deficit of 21-85% electricity in many countries and increasing @ 7-15 % every year. Hence, more thrust is given to alternative renewable and sustainable source of energy i.e. Solar Power. Although, solar radiation is freely available, it has limitation and not so cost effective to afford and reliable to everyone.

Keywords: Solar, Radiation, Power, Micro Irrigation, Design, Watt.

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GUIDANCE FOR INVESTMENTS IN IMPROVED IRRIGATION SERVICES

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ABSTRACT

Population growth, rapid urbanization, economic growth and changes in dietary preferences continue to increase the demand for agricultural produce. The 1996 World Food Summit estimated that 50 to 66% of required gains in crop production would come from irrigated agriculture; noting that yields on irrigated land are typically double that of rain-fed agriculture. Notwithstanding the increasing importance of irrigated agriculture many schemes are currently considered to be under-performing. Irrigation systems, particularly large systems, provide considerable local and national benefits in terms of food and energy security, employment, economic growth and ecosystem services. Substantial investments continue to be made, by governments and international development finance institutions, to create and rehabilitate large-scale irrigation systems; however the performance and sustainability of many of these projects are below expectations. ADB commissioned a regional technical TA7967-REG Innovations for More Food with Less Water in 2011 to provide new insights to guide future investments in rehabilitation and modernization of irrigation.

This paper presents a revised definition of irrigation modernization and recommendations on key issues to be considered in design of investments in irrigation system performance.

Keywords: Modernization, Definition, Irrigation services, Reliability, Flexibility, Investment decisions.

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FINANCIAL CONSTRAINT TO IRRIGATION EXPANSION IN ETHIOPIA AND ALTERNATIVE STRATEGIES FROM ASIAN EXPERIENCE

Mekonnen B. Wakeyo[1], Senayit Shumi[2], and Naoko Oka[3]

ABSTRACT

Despite having profitable irrigation endeavors by smallholder farmers in Ethiopia, it is not expanded to cover the surrounding rain-fed dependent poor farmers. Because of lack of irrigation, the poor smallholder farmers expand their rain-fed land to increase their harvest instead of intensifying their limited landholding to increase yield and output. Recently, Ethiopia approved a strategy and listed ways of investing in irrigation such as allocating government budget, targeting financial sustainability and cost-recovery, extending credit facilities and bank loans for community based small-scale irrigation projects and mobilizing financial resources from external sources; but there are limited achievements in increasing the share of irrigated land in the total arable land which is only 5% of 11.7 million ha and this share is unchanged for long time.

Using quantitative and qualitative analysis, this study explored constraints to expanding irrigation at microeconomic level and evaluated the financing system at national level to compare it with the Asian experience of financing irrigation. A case where irrigation-scheme expansion is possible but not realized is Wonji Kuriftu Irrigation Scheme in central Ethiopia. The findings show that though profitable and cost-effective, financial and institutional gaps limit the expansion of a small-scale irrigation schemes in Ethiopia and the low share of irrigated land remained very low since the 1970s. Asian experience of financing irrigation schemes increased the share of irrigated land in the potential. To increase their share of irrigated land, Asian countries had a 'big push' investment in their irrigation history and they consistently allocated sufficient agricultural budget and encouraged private banks to lend for local and individual farmer investments. Ethiopia needs to supplement local borrowing alternatives to subsidies and donor-pledges to finance the expansion of irrigation and need to have a 'big push' in irrigation investment to feed its population. Designing innovative system of financing irrigation is imperative and accordingly some alternatives of financing are suggested.

Keywords: Irrigation expansion, Small farmers, Financing irrigation, Experience, Asia, Ethiopia.

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WHAT ROLE FOR PPPS IN IRRIGATION: EXPERIENCES FROM SUB-SAHARAN COUNTRIES

Michael Bruentrup[1], Waltina Scheumann, and Annabelle Houdret

ABSTRACT

Water plays a key role in adapting agricultural production to climate change impacts in order to maintain and even increase food production thus contributing to food security. In sub-Saharan African (SSA) countries, food insecurity is „directly related to insufficient total food production, in contrast to South Asia … where food insecurity is primarily caused by poor distribution and lack of purchasing power" (IEG, p. 49). Those countries which still have a significant potential for expanding the area under irrigation, namely countries in SSA, under-investment in water / irrigation infrastructure is common and hampers development. According to FAO projections to 2030 (2014), the area to be irrigated can be expanded by 40 million hectares in the group of developing countries taking into account land and water availability and suitability.

One approach to unlock the irrigation potential is Public-Private Partnership (PPP) projects. PPP projects can be a crucial factor of structural rural transformation with irrigation being in the driver's seat, but they are not the silver bullet since circumstances differ in terms of irrigation potential, regulatory capacity of public administrations, and of the farmers' and policy makers' willingness and ability to go for such arrangements.

Based on insights in PPP projects in irrigation from SSA countries (e.g. Malawi, Swaziland, Tanzania, and Zambia), issues will be presented which are critical in the initial phase of concluding PPP arrangements.

The PPP projects reviewed are highly diverse, with context-specific arrangements related to irrigation investment, and irrigation scheme management. All PPPs presented include in one or the other way smallholders, but to a varying degree: large-scale commercial farms with smallholders as out-growers; block farming where smallholders merge their plots, and members organize production through farmer-owned companies; hybrid business models which combine large plantations and smallholders where the latter hold equity in a larger entity; and independent farming units of varying size where irrigation services are provided by a private management unit to smallholders.

PPPs entail opportunities but also risks for all parties involved: sharing investments, setting up adequate payment schemes and financial guarantees are key for the private partner engaging in the investment but also for smallholders if they are involved in schemes together with large agro-enterprises or are marginalized by such investments. In the initial phase of negotiating PPPs, a critical issue in SSA is customary land tenure with subordinate water rights, and their conversion into secure land titles and water rights while not compromising existing users. Here, governments are asked to protect small-holders vis-à-vis large agribusiness firms, and to protect water and land resources. Whether public institutions are able and have the capacity to fulfill the many regulatory functions in the PPP projects screened will be assessed.

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MOBILIZATION AND ALLOCATION OF FINANCIAL RESOURCES FOR DEVELOPMENT OF IRRIGATION AND DRAINAGE PROJECTS IN INDIA

Shivaji Sangle[1]

ABSTRACT

The most difficult part of planning in India, and for that matter in any country of the world, is the mobilization of financial resources. It is easy to plan and fix targets for various priority sectors of the economy but it is difficult to find the necessary finances to implement the planned projects. The government of India taxes the public and uses the proceeds for economic development; it collects the savings of the public in various ways; it floats loans within the country and also raises funds from foreign sources. If all these sources are found inadequate, the Government resorts to deficit financing or uses created money to finance its projects. The sources of finance available to the government may broadly be divided into three categories; (a) domestic budgetary sources, (b) foreign assistance and (c) deficit financing. About 80 per cent financial resources are mobilized form domestic budgetary sources. A sustained and systematic programme for development of irrigation facilities in India was taken up right from 1951 with the adoption of planning for development. Irrigation programmes were accorded high priority in India's development schemes and investment priorities. There is consistent increase in the plan wise financial expenditure on irrigation sector over different plan period. Average expenditure on development of irrigation schemes is progressively increasing thought the plan period i.e. from 1951 to 2015. With the massive investment on irrigation schemes, it become possible to undertake 414 major projects and 1139 medium projects and created more than 110 million hectares irrigation potential at the end of XIth plan period. Utilization of created irrigation potential is better in case of minor irrigation schemes, however it is far from satisfactory in case of major and medium projects.

Keywords: Financing irrigation schemes, Mobilization of resources, Allocation of resources, Irrigation potential development.

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STUDY ON ZHUJI SHADOOF IRRIGATION SYSTEM AND HERITAGE VALUES

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ABSTRACT

Shadoof-well irrigation is one of the oldest type of lift irrigation. The groups of Shadoof irrigation projects located at Zhaojia town, Zhuji city in Zhejiang Province of China are irrigation heritages, which are still in-use. This paper studied on the history, heritage components, engineering characteristics and heritage values of Zhuji Shadoof Irrigation System through field work and literature research. It has been found that the history of two villages the Shadoof irrigation heritage located at could be traced back to 12th century AD when the immigrants of He and Zhao families migrated here. Based on the superior use of groundwater resources by simple Shadoofs and wells, the irrigated agriculture and population gradually developed and villages were built. Shadoof irrigation projects had been widely used in 17th century at latest in Zhaojia by the records of historical documents. It is also showed that ancient people had scientifically realized the mechanism of groundwater cycle and artificially built a dam in the brook to augment groundwater recharge. The paper argues that Zhuji Shadoof Irrigation System with important historical, cultural and technological values is living fossils which witness to history of irrigation civilization, with the suggestion that we should protect this heritage scientifically in view of its better anthropological value more than pragmatic reference for groundwater management for agriculture in the present times

Keywords: Shadoof, Irrigation, Water-lifting machinery, Heritage, Values.

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FOOD SECURITY AND POVERTY ERADICATION THROUGH SMALL SCALE INLAND FISHERIES IN A DISTRICT IN INDIA

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ABSTRACT

India has a vast and diverse potential of fishing resources, comprising 2 million sq. kms. of Exclusive Economic Zone for deep sea fishing, besides a long coastline, innumerable flowing and stagnant water bodies for fish cultivation and fishing. About 14 million fishermen draw their livelihood from fisheries. The main objective of this paper is to study the role of the small scale inland fisheries for food security and eradication of poverty in the Aurangabad district, Maharashtra state, India. The district has total 1867 water tanks, ponds and reservoirs and about 2000 private farm ponds. stratified random sampling technique was adopted to select 514 fishermen families from the district for the study. The study revealed that inland pond and tank fisheries have direct impact on household engaged in fishing and fish culture by way of generation of employment, increase in income and ensuring food security. Hardly, 40 percent fishermen are traditional and work full time in fishing, rest fishermen either work on own land or elsewhere. Almost exclusively men are engaged in fishing however women are involved in diverse ways such as cleaning, feeding the fish, selling the harvest, etc. Aurangabad district has a vast potential for development of inland fisheries. Inland tank reservoir fisheries exploitation and utilization must be made as part of government employment programme and policies of food security, health and poverty alleviation.

Keywords: Inland fishery, Food security, Poverty eradication, Aurangabad, Maharashtra, India.

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EFFECTS OF STRAW MULCHING ON MICROCLIMATE CHARACTERISTICS, EVAPOTRANSPIRATION AND YIELD OF DRIP IRRIGATED WINTER WHEAT IN NORTH CHINA PLAIN

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ABSTRACT

A field experiment was conducted for two consecutive years (2013-2015) to study the effects of straw mulching on microclimate characteristics, energy flux, soil evaporation, evapotranspiration, yield and water productivity (WP)of winter wheat (Triticumaestivum L.) under drip irrigation in the North China Plain(NCP). The results revealed that straw mulching affected air temperature and dew point temperature near the soil surface, but had little effect on relative humidity when compared with non-mulched fields. Mulching increased the turbulent exchange coefficient to some extent, and the transfer coefficient (K) within the canopy was higher than that above the canopy. The mulching had little effect on the soil heat flux (G) and latent heat flux distributions, but obviously increased the sensible (H) distribution during May through June, the H was negative much of the time, and part of the energy needed for evapotranspiration was provided by transfer from the warmer air aloft. There was a linear functional relationship between Hand air temperature differences within canopy and above canopy (T_{cd}- T_{cu}). The straw mulch decreased the soil evaporation (Es), but enhanced the crop transpiration (T).There were no significant differences ($P < 0.05$) in cumulative crop evapotranspiration, crop yield, and WP between mulched (TM) and non-mulched (TN) treatments under adequate drip irrigation.

Keywords: Drip irrigation; Microclimate; Straw mulching; Winter wheat; Water productivity.

Sub-theme 3

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AN INNOVATIVE WATER MANAGEMENT APPROACH FOR FOOD SECURITY OF COASTAL ZONE COMMUNITIES IN BANGLADESH

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ABSTRACT

The polders of the coastal zone of Bangladesh are home to some of the world's poorest and most food insecure people, whose livelihoods depend primarily on agriculture. Despite huge investment in development and maintenance of the polders, and the availability of improved production technologies which have greatly benefited other parts of Bangladesh, productivity in the polders remains very low. Key challenges to agricultural productivity include excessive flooding during the rainy season, lack of access to fresh water and soil salinity in the dry season, and severe cyclonic storms. These challenges will be exacerbated as a result of climate change. Yet there are tremendous opportunities to capitalize on polder ecosystem services (especially tidal river dynamics and dense internal natural drainage networks ('canals')), and existing infrastructure (sluice gates, roads) and community organizations (especially Water Management Groups) to reduce waterlogging and greatly increase cropping system productivity. The work presented here showed that productivity could be tripled in polder in a medium salinity environment by combining improved water management with high yielding rice and *rabi* crops/varieties and recommended crop management practices. Improved water management involved the formation of small water management units by constructing small farm levees/drains to separate lands of different elevation, together with improved management of the sluice gate connecting the canals to the surrounding tidal river. Community cooperation and coordination and cropping system synchronization were also key elements to tripling productivity.

Keywords: Water management, Drainage, Coastal polders, Community participation, Agricultural intensification, Food security.

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INNOVATION FOR POTABLE WATER FROM SALINE AQUIFER: A STEP TOWARD CLIMATE CHANGE PREPAREDNESS

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ABSTRACT

High groundwater salinity at shallow or intermediate depths spreads over 24 million sq. km. around the world (16% of the total land area), affecting 1.1 billion people. The problem is acute in India, where saline groundwater affects an area of about 200,000 sq. km. in eleven states. Salinity occurs primarily due to natural circumstances in the geography and leads to social, economic, and environmental stresses. The unpotability of saline water has a social dimension. Using saline water for irrigation deteriorates soil quality and limits the crops choices and productivity.

Mewat District, Haryana, India, is primarily groundwater-dependent and has highly saline groundwater in 78% of its area. The few villages with fresh groundwater also supply water to adjoining saline areas, through informal water markets. Overexploitation causes fast depletion of fresh groundwater resources leading to encroachment by surrounding saline groundwater.

Climate change projections support the apprehension that there will be further decline in quality and availability of fresh groundwater. The situation will worsen unless communities and stakeholders address the salinity problem.

Rainwater harvesting can address the issue of inadequate fresh groundwater if the rainwater can be stored for later use. Storage structures required to meet a community's demand for water are large and expensive. To provide large storage capacity at low cost, we have demonstrated innovative technique for creating pocket of fresh groundwater within the saline aquifer using hydrostatic pressure under gravity to prevent mixing of harvested rainwater with the existing saline groundwater. The harvested rainwater forms a pocket of freshwater from which potable water can be extracted and filtered. This model eliminates the need for expensive large storage structures and puts an otherwise unutilized saline aquifer to work, thereby creating a local source of potable water. This solution is highly scalable and replicable and can be deployed for domestic and agricultural and other purposes across households, agriculture farms, and community level. For irrigation needs in saline groundwater areas this source of quality fresh water can be used for conjunctive use.

Keywords: Rainwater harvesting, Hydrostatic pressure, Saline aquifer, Freshwater pocket.

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WATER MANAGEMENT SYSTEM IN THE UKRAINIAN DANUBE RIVER AREA FOR FOOD AND ENVIRONMENTAL SAFETY

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ABSTRACT

The development of irrigation areas in the Danube River Basin is one of the activities to ensure food security of Ukraine. However, watering with the mineralized waters of the Danube lakes can lead to land degradation, higher soil salinity and alkalinity. To reduce and avoid these negative processes, a water management system is proposed for implementation. For the comprehensive assessment of irrigation water quality, the existing methods and applicable standards were studied. Based on a balance method, the permissible salt content in irrigation water and consequently applied irrigation rates is calculated. To prevent alkalinity, some comprehensive ameliorative measures are recommended for implementing. It is proved that the water from the Danube River and Cahul lakes is suitable for irrigation. The water from Yalpug, Catlabuh and Kytai lakes can also be used in limited amounts. The irrigation rates calculated for corn, sunflower, and winter wheat for a rather long period are shown. The balance method enables to calculate a safe irrigation rate in view of salt content for each irrigation source. To prevent soil alkalinity, it is recommended a range of melioration measures, such as gypsum and phosphogypsum application, deep plowing, watering with small rates of 300-350 m^3/ha. Numerical modeling of irrigation regimes for winter wheat allowed determining biologically optimal and environmentally friendly water-saving irrigation regimes in view of water quality of each irrigation source in the Danube areas.

Keywords: Management, Salinity, Alkalinity, Water quality, The Danube lakes, Irrigation rates, Water-saving irrigation regimes, Balance method.

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MULTI CRITERIA TOOLS AND METHODS FOR SUSTAINABILITY STUDIES IN IRRIGATED AREAS

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ABSTRACT

The state owned TRAGSA Group companies in Spain has introduced a multi criteria analysis for irrigation by integrating social, economic, technologic, institutional, legal and environmental components under changing priorities and relevance, and under climate change perspective.

These methodologies and tools have allowed the technical assistance for the elaboration of works on national and regional entity irrigation areas. The highlights are the support to the Spanish Irrigation Plan(PNR) studies, the Special Plan for the Alto Guadiana aquifer, Murcia Region Irrigation Plan, Environmental Monitoring Program of PNR and some pilot irrigation areas, Analysis of costs of regulation and use of irrigation water, Study of the organization of the workflow and the production in the irrigating communities and others. This array of different projects led to a wider approach to irrigation sustainability.

A multi criteria tool for irrigation is shown as an applied example of those previous experiences and their integrated philosophy. The software was developed in a GIS platform for the identification of the potential irrigable areas in Argentina. This consulting was done for the FAO (2013-2015), within the Provinces Agricultural Services Program (PROSAP), which has an agreement to improve the agricultural sector efficiency and the living conditions of the small and medium size producers.

This multi criteria tool integrates and exchanges alphanumeric and cartographic information into a thematic structure of five blocks of analysis (technical, environmental, social, economic and institutional) generating irrigation geo-referenced layers. Using the combination of the GIS coverage and its multi criteria weighting, it allows the analysis of the irrigation sustainability with different indicators and climate change scenarios, and produces the estimate of irrigation potentiality index for each area.

Keywords: Multi criteria tools, Irrigation, Sustainability, Indicators, Climate change.

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USE OF DRAINAGE WATER FOR IRRIGATION OF QUINOA IN A MEDITERRANEAN ENVIRONMENT

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ABSTRACT

Productivity in agriculture is to be enhanced in the near future with a smaller amount of available fresh water. Quinoa (*Chenopodium quinoa* Willd.) is a promising crop for food security in dry areas. The objective of this study is to evaluate the effect of drainage water applied with a line-source sprinkler system at different growth stages of quinoa grown in the Mediterranean region of Turkey in 2014 and 2015 on yield, yield components, vegetative growth, water use efficiency and salt accumulation in the plant rootzone. Total amount of drainage water applied to treatment (I1) was 344 and 400 mm; and total amount of seasonal water use (ET) was 514, and 459 mm; for two experimental years. Irrigation levels (I1-I4) influenced significantly quinoa yields and yield components. Maximum yield came from the I1 as 4880-4510 kg ha^{-1}; and the lowest yield was from the rainfed treatment as 1880 and 1430 kg ha^{-1}, respectively, in the two study years. Significant positive linear relationships were found between the seed yield and ET. The yield response factors (ky) were 1.17 in 2014 and 1.06 in 2015. Data on yield and some quality parameters such as the harvest index, 1000 seed weight, leaf area index as well as plant height at harvest were highest in I1 treatment. Not only the total yield, but also yield components increased with higher irrigation levels.The experimental results revealed that there was no significant difference in the WUE among the treatments (0.95 to 1.03 kg m^{-3} in the 1st year and 0.94-1.10 kg m^{-3} in the 2nd year). Soil salinity at the beginning of the season varied from 0.63-0.72 dS m^{-1} and application of drainage water resulted in its increase up to 1.69 dS m^{-1}. Soil salinity decreased with increasing depth in all treatments. In conclusion, full irrigation using drainage water is recommended for sprinkler irrigated quinoa in order to obtain higher and better quality yield in the Mediterranena region of Turkey. Thus, drainage water can safely be used in quinoa production without soil degradation in this region since the winter rainfalls are sufficient enough to leach salts out of crop root zone.

Keywords: Drainage water reuse, Quinoa, Abiotic stresses, Line-source sprinkler.

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AGRICULTURAL RADIAL COLLECTOR WELLS IN SOUTH KOREA

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ABSTRACT

Radial collector well (RCW) has been managed by Korea Rural Community Corporation (KRC) since 1983, installing 98 wells for agriculture in rural area over the country. Among them, 20 are installed upstream of 5 subsurface dams and the remaining are installed regardless of the subsurface dam. Most of RCW have been developed in 1980s and 1990s, and 81 wells have served for more than 20 years after construction. The number of horizontal arms for agricultural RCW varies from 9 to 28, with length and diameter being 10-30 m and 65 mm, respectively. The central caisson with an inner diameter of 3.5 m was commonly constructed to a depth of 10 m. The maximum pumping rates in RCWs, which are located at distances of 10 to 1,200 m from the river, are 2,000-5,000 m^3/day. Several RCWs have been developed to siphon type to prevent the fine sand inflow along the screen in the horizontal arms. However, pumping rates gradually decline because of the influx of small particles from the aquifer matrix, the precipitation of minerals due to the water-rock interaction, and sediment accumulation in the pipe due to bacterial action. Therefore, KRC has established the guidebook for monitoring and improving well efficiency through physical/chemical treatment, well logging, and hydraulic tests and managed RCWs periodically with its rehabilitation methods.

Keywords: Radial collector well, Subsurface dam, Horizontal arms, Pumping rate, Well efficiency, Rehabilitation.

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MANAGEMENT OF THE IRRIGATION WATER IN SOUTH OF UKRAINE

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ABSTRACT

Ukraine has limited water resources and its spatial distribution is uneven. Considering regional displays of global climate change the questions of rational water use and integrated management of the available resources of surface and groundwater becomes more urgent.

An approach to integrated water resources management as the development and implementation of measures aimed at achieving “good” state of water for specific water bodies and improving quantitative characteristics of water use by fitting the current water balance of the area in accordance with target one is proposed in the paper. For these target values, the following are minimized: non-technologically-based water losses in irreversible water use, filtering and discharges; the volume of insufficiently treated wastewaters; total water intake to the needs of branches of the economy in the region under consideration.

Keywords: Irrigation, Water management, Water use, Agricultural crops.

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ENSURING SUSTAINABLE FOOD PRODUCTION IN AFGHANISTAN IN SPITE OF CLIMATE CHANGE THROUGH SYSTEMATIC WATER MANAGEMENT

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ABSTRACT

Water resources in Afghanistan are limited. Population growth and cyclic droughts have been adding pressure on the available water resources. Moreover, climate change has been adversely affecting the snow reserves of the country. Vis-à-vis these adversities, attempts to ensure sustainable food production is important.

Before the three decades of war, Afghanistan was self-sufficient over the staple food (wheat), and had 3.1 million hectare (Mha) land under irrigation. However, the situation deteriorated a lot after the war. Afghanistan has available water of 2377 m^3/person, 50% of which is enough to irrigate more than 5.5 million hectors agricultural land. The agriculture sector has not been able to fully utilize the available water potential to support needed agriculture production and increase the irrigated area from 2.1 Mha to its former level of 3.1 Mha.

The timely and reliable assessment of water resources, its monitoring, systematic exploration and development is of paramount importance. For this, it is necessary to employ modern methods of surveying, investigations, design, and implementation.

This paper will focus on key water management actions appropriate in Afghanistan for sustainable food production in the context of changing climate. It will first characterize the current status of the different river basins in terms of water availability and will also present the scenario of impact of climate change on the existing water resources. Based on this assessment, it will outline suitable climate smart approaches that might contribute to ensuring sustainable agriculture.

Keywords: Climate change, food security, sustainability, Afghanistan.

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ASSESSMENT OF NUTRIENT LOADS REDUCTION FROM PADDY RICE FIELDS IN KOREA UNDER BMPS SCENARIOS

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ABSTRACT

Nutrient export from paddy rice is one of the major problems in water quality management in Korea. The objective of this study was to analyze the nutrient load balance on paddy BMP (Best Management Practices) scenarios through monitoring and modelling and to evaluate their effectiveness on nutrient loads reduction. A paddy fields in Saemangeum watersheds was selected to collect hydrologic and nutrient water quality data. Paddy farming factor of drainage outlet height and fertilizer type were monitored and five BMP scenarios based on the monitored scenarios were simulated. Irrigation, ponding depth, drainage and infiltration of paddy fields were measured using water level gauges, flow meter and stage-discharge relationship, while water samples were collected and analyzed for water quality. The water balance analysis showed that drainage outlet height has effect on drainage amount reduction by 24.2%. Overall, nutrient average concentration was similar among the treatment, while T-P (Total-Phosphorus) concentration of fertilizer type was lower than other BMP scenarios (p-value<0.05). Paddy field drainage T-N (Total-Nitrogen) loads were reduced by 27.1% and 29.0% for two farming factor as compared to conventional farming. T-P loads were also reduced by 38.0% and 26.2%. A field scale model, CREAMS-PADDY (Chemical, Runoff, and Erosion from Agricultural Management Systems for PADDY, was used to simulate paddy field drainage loads. The data collected from the study area was used for model calibration and validation. The validated model was used to simulate BMP scenarios during long-term period. Simulated results showed that soil test fertilization and drainage outlet height control were effective on nutrient loads reduction. The combination of these two farming factor resulted in the greatest reduction by 29% and 37% for T-N and T-P (p-value<0.001). The study results revealed that outlet height control and soil-nutrient-based fertilization were effective on nutrient loads reduction and the combined BMP scenarios help to protect the downstream water quality.

Keywords: Paddy, Nutrient, Water quality, CREAMS-PADDY, Load balance.

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FARMERS' PERCEPTION OF WATER MANAGEMENT UNDER DROUGHT CONDITIONS IN BADAKSHAN PROVINCE, AFGHANISTAN

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ABSTRACT

Drought is a recurring natural hazard in Badakhshan Province of Afghanistan.The objective of this study is to specify farmers' perception and understanding about prevalence and characteristics of drought, such as frequency, environmental hazards, and socio-economic impacts, and coping and mitigations strategies to be adopted for drought-proofing. A questionnaire, designed based on various earlier socioeconomic drought-related researches, was completed by 178 farming households. In addition, various water resource management agencies at the national level, water specialists, climate change experts, and agricultural engineers were also consulted. The results show that drought has brought about serious diverse economic impacts such as loss of employment, reduction in crop yield and livestock production which has worsened farmers' livelihood situation and subsequently weakened their economy. Social impacts reported migration, hopelessness and sense of loss, conflicts because of water scarcity, health impacts, and effects on schooling of children, malnutrition, and limited food preferences. Farmers reported widespread droughts brought about high extent environmental impacts such as increase in average temperature, pasture-forest degradation, deteriorated water quality, damage to fish habitat-wild life, and groundwater depletion. Farmers use their local techniques and practices to lessen the drought effects and thus have adapted varieties of options, but results show that farmers' preparedness to adapt led to implementation of more reactive and indegenous adaptation measures because of low education, low income, and possibility of off-farm source of income. Although farmers are aware of drought impacts, they give less preference for adoption. The level of satisfaction of farmers from the government was almost zero as the government has not undertaken any notable relief measure yet. It is expected that this study will support policy makers within government, development agencies and communities in Afghanistan to develop drought adaptation policies.

Keywords: Adaptation strategies; Agriculture; Drought impacts.

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EVALUATION OF THE SALINITY OF GROUNDWATER USED FOR IRRIGATION AND RISKS OF SOIL DEGRADATION: CASE STUDY OF THE ISSEN PERIMETER IN THE SOUSS-MASSA, MOROCCO

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ABSTRACT

In the Issen irrigated perimeter from Souss-Massa, under a semi-arid climate, irrigation is essential for most crops. Therefore, groundwater is being increasingly used. Hydro-chemical and statistical studies have been conducted to find the major and secondary elements of the groundwaters. Sampling was done over two years (2013 and 2014) spread over three seasons from thirty six wells spread across the studied plain. The values recorded during the sampling period showed that the majority of analyzed wells are highly saline with an average salinity of 2 dS/m. Chemical analyses reveal a wide variety of chemical compositions; samples are divided between two facies: Sulfated calcium and magnesian facies and sodic chlorinated facies. Then, statistical analyses of the studied parameters show great variability and the results of analyses were used to establish maps of salinity and SAR risk of irrigation water.

Keywords: Morocco, Hydrochemistry, Statistics, Irrigation, Salinization, Issen irrigated perimeter.

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MODERNIZATION OF IRRIGATION SCHEMES THROUGH TRAINING OF WATER USER ASSOCIATIONS IN THE RAPID INTERVENTION PROGRAM

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ABSTRACT

The Rapid Intervention Program (RIP) is unique as it is design to capture the knowledge and experience of operators and users of irrigation schemes in order to identify problems and needs for better management and rehabilitation. The RIP was developed over a twelve year period by Texas A&M Agricultural Extension Service, and is a structured and systematic approach for analyzing the distribution network and on-farm irrigation of irrigation schemes, and developing recommendations on improved management strategies. RIP is designed as a low-cost, user-friendly and versatile approach that takes advantage of the knowledge and experience of the scheme operators and managers, and involves the combination in one single tool of several rating forms: the Head Survey, the Canal and Gate Evaluation, and the On-farm Survey. Included in the RIP is also the building of a GIS map, needed to apply the tools.

This paper provides an overview of the RIP components as applied to two water users associations in Iraq and to a large irrigation district in Texas. RIP was found to be easy to learn by both Iraqi and US participants, and was effective at identifying major problems in the irrigation schemes. RIP also identified water management problems that could easily be corrected with modification in practices. In the Iraq project, a key component was the training of collaborators so that they could implement and transfer the RIP to other irrigation schemes in Iraq. The results show that knowledgeable individuals can be trained quickly in how to analyze and implement the RIP.

Keywords: GIS, Rapid Intervention Program (RIP), On-farm, Iraq, Survey.

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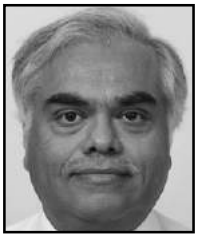

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SUB-THEME 3

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Brief CV's

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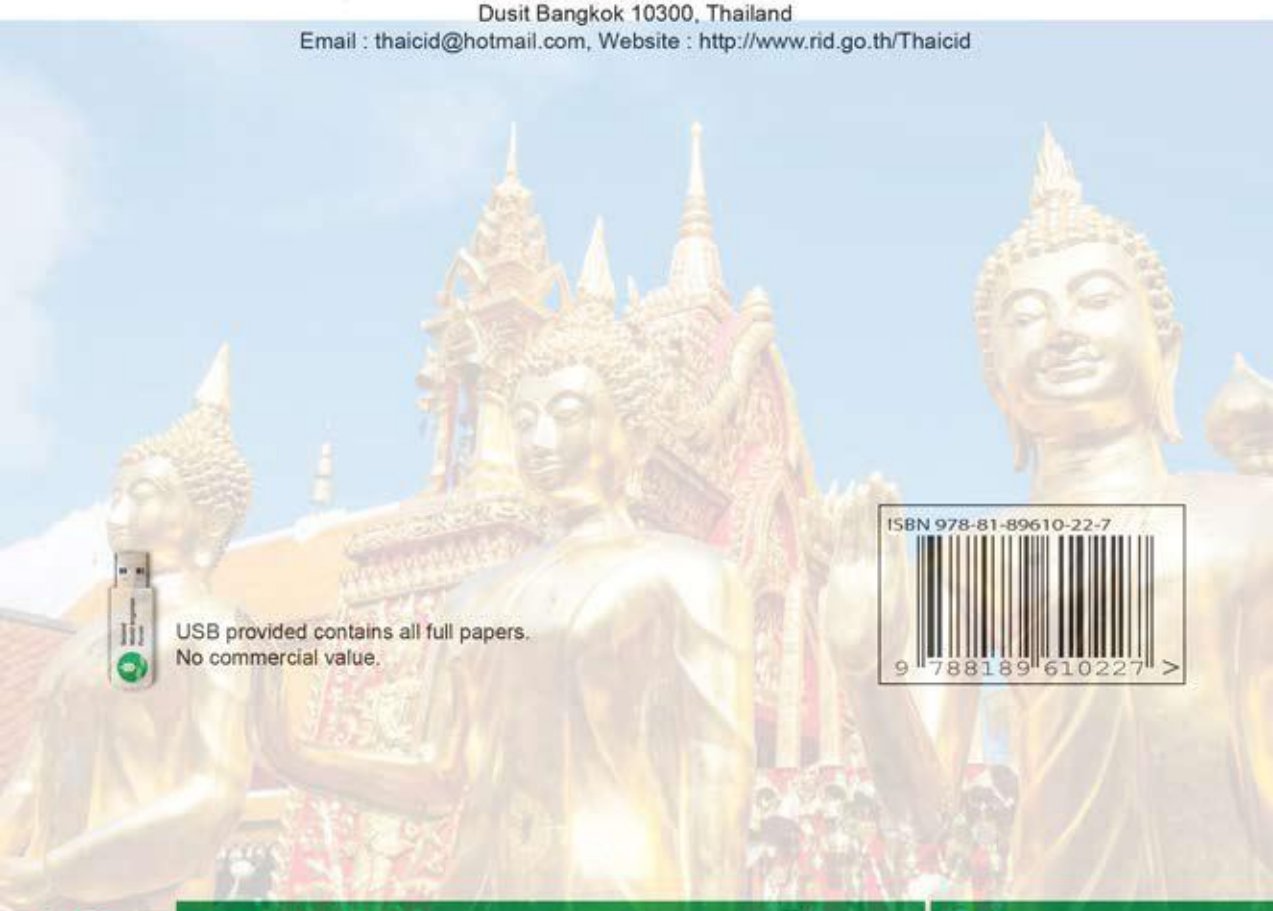

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