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 the 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.

1. INTRODUCTION

CSA has been adopted by the Development community as the default concept for achieving three socio-ecological objectives: mitigation of environmental damage that traditional farming practices have caused since the Green Revolution of the 1970’s and 80’s; adaptation of sustainable agricultural methodologies and systems for changing ecological and climatic conditions; and improved productivity and, by extension, improved livelihoods, for farmers at all scales and scopes.

Reliable and valid evidence illustrate that CSA can be successful. In a seminal study of 12 million growers farming 37 million hectares, Pretty et al, found that these
methodologies are of significant and positive utility. Successful implementation of sustainable agricultural practices such as minimum crop tillage and integrated pest and nutrient management have helped increase average yields by an average of 79% (Pretty, 2005). Greenhouse gas emissions have been reduced by an average of 0.35 GT/CY/Ha by using CSA practices. "Estimated elasticities indicate that, on average, a 1 percent increase in agricultural productivity level will reduce incidence of poverty by an average of 0.31 percent" (Hussain & Hanjra, 2004).

However, the FAO crop production index of LDCs indicates a reduction of overall productivity from 2010 to 2011 and a paltry increase of 2.65% from 2010-2012 (FAO, 2013). Figure 1, below, illustrates the growth of agricultural production from 2005-2012. Over the next 30 years agricultural production in LDCs has to increase by 100% to cope with growing populations (FAO, 2009).

![LDCs CPI 2005-2012](image)

**Figure 1.** Crop production index in LDCs from 2005-2012 (FAO, 2013)

### 1.1 Current Paradigm

The current paradigm for agricultural development in the LDCs is to address the challenges of poverty reduction through improved agricultural production by funding government or NGO projects directly to national governments in the form of loans, grants, direct aid or donations. Agriculture has been the beneficiary of direct funding, subsidies, research and development. From 1995 to 2009 total Net Official Development Assistance (ODA) to LDCs rose from $17 billion to $40 billion (in current US$) (UNDP, 2010). In 2010, net ODA flows from members of the Development Assistance Committee (DAC) of the Organization for Economic Development and Cooperation (OECD) reached $128.7 billion, which is the highest level of aid in the history of the (OECD, 2013). The most complete source of data on government expenditures on agriculture in the countries of the developing world indicate that levels of expenditures on agriculture for all 67 countries in the Statistics of Public Expenditure for Economic Development (SPEED) database increased from $55 billion in Purchasing Power Parity (PPP) in 1980 to $205 billion in 2007 (Lowder & Carisma, 2011). By 2010 the total ODA from all sources to LDCs reached $400 billion, up from $135 billion in 2000. During that same period annual growth from agricultural production in LDCs grew from -1% in 2000 to 2% in 2010.

Current institutional frameworks do not provide epistemic or agro-economic support for LDC smallholders. Current institutional paradigms consist of: the International
Finance Corporation (IFC) which addresses poverty reduction by identifying public/private investment strategies between private investors and agribusiness concerns; the World Bank's International Development Assistance (IDA) program which addresses poverty reduction at the state level, by formulating and endorsing Country Assistance Strategy (CAS) programs that follow the specific precepts individual country's Poverty Reduction Strategy Program (PRSP); agricultural-focused NGOs which adopt a participatory-proactive model, the central task of which is to mediate or bridge between public sector agricultural institutions and their farmer members. These smaller NGOs that are focused on smallholder farmers are primarily altruistic organizations, many from faith-based institutions, that are not economic stakeholders in agricultural productivity; and, Water User Associations (WUAs) which are often cited as the key, local contributory institutions to agricultural productivity which serve as the central agent for Participatory Irrigation Management (PIM). Institutional theory places WUAs at the 'group' level and in the 'collective action' sector (Dorward et al., 2009) and their importance is embedded in infrastructure and market management, important and necessary components for development, but do not directly impact increased agricultural productivity. In the final analysis these organization do not have "skin in the game". The livelihoods of the Development community are not inextricably linked or financial dependent on the success or failure of the target communities.

The Climate-smart Irrigation Concept: The paradigm of climate-smart irrigation posits that the principal agent relationship be transformed from a donor-recipient model to a commercial relationship between the manufacturers of products in the input value chain for agricultural production, the distributors of these products who act as the professional link between the manufacturer and the grower, and the grower him or herself.

2. CLIMATE CHANGE

A key question is how does the irrigation distributor contribute to climate change implications for agriculture? A critical component of climate-smart agriculture is to cease the conversion from forested or savanna to agriculture. Because of the poor access and availability of robust irrigation systems, the default practice of farmers in the LDCs to increase yields has been to engage in "extensive" farming, which is to say that they rely on converting forest or savannah acreage to farmland to increase production, rather than "intensive" farming which means improving production on current farming acreage. "Extensive" farming, or adding acreage, is the most egregious step that transforms land from a carbon sink to a carbon source. In other words, extensive farming is the single greatest cause of greenhouse gas emissions. Table1 illustrates the importance of not expanding agricultural acreage.

<table>
<thead>
<tr>
<th>Improved land management practices</th>
<th>GHG (tCO₂eq/ha/yr) for warm-dry region</th>
</tr>
</thead>
<tbody>
<tr>
<td>Soil nutrient management</td>
<td>0.33</td>
</tr>
<tr>
<td>Tillage and residue management</td>
<td>0.35</td>
</tr>
<tr>
<td>Water management</td>
<td>1.14</td>
</tr>
<tr>
<td>Set-aside land and land cover change</td>
<td>3.93</td>
</tr>
<tr>
<td>Restoration of organic soils</td>
<td>70.18</td>
</tr>
<tr>
<td>Restoration of degraded soils</td>
<td>3.45</td>
</tr>
<tr>
<td>Application of manure/bio-solids</td>
<td>1.54</td>
</tr>
</tbody>
</table>
2.1 Extensive vs Intensive Farming

The important contribution that professionally supported irrigation systems can make toward mitigation of traditional practices is to support the proliferation of intensive agriculture (improving yields on current land) and reduce growers’ dependence on extensive agriculture.

Figure 2 illustrates the amount of land (set-aside land) that is not a source for carbon as it is not used in agriculture. However, for the purposes of this research, this figure also illustrates the distinction between extensive and intensive agriculture. The Asian graph indicates that agricultural production was increased due to improved production on current land. In Africa, however, agricultural production was increased by expanding agricultural land.

![Figure 2. Extensive vs Intensive agriculture](image)

2.2 The Climate-smart Irrigation Principal Agent Relationship

Figure 2 represents the climate-smart irrigation principal agent relationship. This triangular, interlinked and financially interdependent relationship is the default model for distribution of goods in the input value chain in the Developed world and is now emerging in East Africa.

![Figure 3. The climate-smart irrigation principal agent relationship](image)
Agriculture is a science and an art and to achieve the ambitious goals for the LDCs over the next thirty years, no shortcuts are possible. This means that the products used by growers in the LDCs have to be professionally developed, designed and installed at the same or better quality than those used in the Developed world. It means that the uniformity of irrigation water in the field has to be of the same high standard in the Developed world. It means that the level of support growers require in the LDCs has to be available and accessible just as it is in the Developed world.

2.3 The Climate-smart Irrigation Model

Climate-smart irrigation consists of three basic principles: best products; professional support; and robust data analysis and evaluation. The model is illustrated in Figure 3.

2.4 Best available technology

The first principle calls for best available technology. In the Developing world, too frequently, drip irrigation products are provided because of their relative reduced costs when compared to drip irrigation products in the Developed world. The companies that sell their products cite the benefits as overall reduced cost and the absence of the drip emitter in the dripperline asserting that the dripper is the major cause of clogging. In the professional community of irrigation and in the agricultural market in the Developed world such a product would be summarily rejected. The drip emitter is the key factor for irrigation uniformity and imperative for improved production.

2.5 Professional input distribution

The second principle is that all products are to be provided in a commercial framework by a professional irrigation distributor who provides the following services:

1. Local supply of equipment,
2. Implementation guidance,
3. Training on the use of equipment,
4. Immediate source of support,
5. Irrigation design and engineering,
6. Industry knowledge & innovation.
7. Valuator of new products, 8. Links to manufacturers
9. Distribution of supporting products, 10. Agronomic support
11. Plant disease identification, 12. Market access support
13. Manager of financial tools to promote innovation including credit
14. Manager of manufacturer warranties, 15. Source & transfer of knowledge
16. Developer and provider for local, skilled employment

It is critical to understand that this research focuses on the irrigation distributor as the key principal agent for climate-smart irrigation. However, it is equally important to point out the extent to which the agricultural/irrigation industry, as a whole, is vital to the success of the grower. In the United States, for example, approximately 3 million people farm crops. Over 25 million people work in the agricultural sector. These people work in manufacturing, distribution, human resources, transportation, marketing, sales, advertising, conferences, research organizations and design. Fully 88% of all agriculturally-based jobs are 'non-farm' jobs (USDA, 2015).

2.5 Robust data management

The third principle of climate-smart irrigation is the collection, analysis and evaluation of valid and reliable data. The purpose of this model is to provide a framework for replicability and generalizability. Therefore, data that are used to evaluate these regimes must be robust. For example, while reports are common about the adoption of drip irrigation in sub-Saharan Africa, further studies indicate, for example, that within two years up to 78% of all adopters in Kenya between 2005-2007 dis-adopted the technology (Friedlander et al., 2013). The most robust data are available from the distributor who supplies and supports equipment and keeps track of purchases of whole goods and spare parts.

3. CONCLUSION

In order for smallholder farmers in LDCs to increase productivity, enjoy higher marginal profits, change agricultural land from carbon sources to carbon sinks, create associated employment opportunities, develop greater political and economic strength and influence, an integrated and holistic approach to agricultural management is critical. The key to achieving those objectives is implementation of technology and increasing the knowledge base. The irrigation distributor stakeholder is the critical agent for achieving these goals.

REFERENCES


