COLLECTION AND ANALYSIS OF WATERSHED HYDROLOGICAL DATA (PRECIPITATION, RUNOFF, SEDIMENT AND NUTRIENTS YIELDS)

Reducing Land Degradation and Farmers' Vulnerability to Climate Change in the Highland Dry Areas of North-Western Ethiopia

TECHNICAL REPORT OF EXPERIMENTAL ACTIVITIES

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Implemented by

ICARDA
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About the Project

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About ICARDA

The International Center for Agricultural Research in the Dry Areas (ICARDA) is the global agricultural research Center working with countries in the world's dry and marginal areas, supporting them for sustainable agriculture development to help increase their productivity, raise incomes for smallholder farmer families, improve rural nutrition and strengthen national food security. With partners in more than 40 countries, ICARDA produces science based-solutions that include new crop varieties (barley, wheat, durum wheat, lentil, faba bean, kabuli chickpea, pasture and forage legumes); improved practices for farming and natural resources management; and socio-economic and policy options to enable and empower countries to improve their food security. ICARDA works closely with national agricultural research programs and other partners worldwide in Central Asia, South Asia, West Asia, North Africa, and Sub-Saharan Africa.

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Synthesis

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Summary report

The bio-economic and climate change modeling work under this project aims at mimicking the current decision making process of farmers in a systems' context by intermarrying both the socioeconomic and biophysical dynamics in the Gumera-Maksegnit watershed. Simulations are used to predict the likely outcomes at the system level in general, and different farm typologies in particular, under several combinations of social, economic, bio-physical, policy, institutional, market, technological and adaptation strategies under climate change scenarios. Due to the variability in topography, soils, rainfall, agronomic practices and livelihood circumstances at the watershed level, a bio-economic model that can describe the system is needed. Practices at the farm level are usually site specific. It is important that these are modeled to be able to generalize across the 6000 ha watershed and beyond.

Therefore, the ultimate goal of this study is to provide insight on the effects of various technological, policy, institutional, environmental, biophysical, adaptation strategies and marketing interventions under different climate change scenarios, different climate change adaptation strategies on farmers livelihoods and help decision makers by identifying the optimal courses of action for achieving the desired outcomes (including poverty reduction, food security and sustainability) at both the system and sub system levels and if possible at household levels with special emphasis to the differential effects of the different policy, institutional, technological and climate change on the different farm household typologies. This will be useful especially in the effort to identify the most vulnerable farm household typologies and develop mitigation and adaptation strategies that will reduce the risk of facing irreversible damages. This modelling research is still ongoing and is the subject of a PhD research that will continue until the end of 2017.

1 Data collection and analysis

Data collection, calibration and verification of the model.

Primary and secondary data necessary for the development, calibration and validation of the bio-economic model were collected. The secondary data collected include detailed soil physical and chemical data, erosion data at plot level for different conservation technologies and crops over several years (from researchers, farmer-managed experiments, and farmers' plots), crop yield data on different soils, different agronomic practices and under different conservation technologies, climatic data and other biological data's from Gondar Agricultural Research Center Researchers and the Amhara Regional Agricultural Research Institute. Secondary data on technical, economic, and environmental data were gathered from different sources. Particularly, bio-physical data collected by GARC and ARARI during the previous five years were also obtained for this modelling work.

Primary data on detailed household and plot-level properties and dynamics were collected using a complete census of the farm households in the treated and immediate control (untreated) sub watersheds and using random sampling for farm households which are far away and outside the treated and untreated sub-water sheds but part of the bigger watershed. The primary data were collected from a total of 293 farm households using structured questionnaires which were developed exclusively for this purpose. Plot-level data were also collected by visiting and measuring (by triangulation) and observing all plots and by interviewing the households owning or renting the plots. In addition to the semi-structured questionnaire, personal observations and group discussion were made using checklists.

Analysis of the farm household data has started and farm household typologies were constructed. Two multivariate statistical techniques namely, Principal Component Analysis (PCA) and Cluster Analysis (CA) were sequentially used.

2 Modelling framework and expected results

Model application for rainfed system analysis.

The model, once proved suitable and reasonably describing the system parameters will be used to analyze the dynamics of the system. A range of scenarios will be created and simulated to identify the major constraints and solutions to such constraints to improved system productivity. The contribution of various constraints will be quantified by a set of sustainability indicators.

Bottom up integrated land use optimization will be used at both household (subsystem) and watershed (system) levels. Integration helps to better analyze the interactions and feedback mechanisms between natural processes and socio-economic responses of land use systems. The dimensions of integration include concepts and theories, data, models and scenarios. Bottom up approach considers detailed spatial representation of land units, technologies and management options, policy instruments and measures. The bio-economic modeling work under this project will use two modelling frameworks- one for capturing the bio-physical relationships and the other for economic decisions. The calibration of the EPIC model for biophysical simulation has been started. The model will serve as an analytical tool to study the effects of cropping system management, weather, technology and other innovations on productivity, resource and environmental sustainability.

The development of an economic decision tool has also been started. Given that agricultural production in the watershed is characterized by response farming, the sequential linear farm household optimization model, linear both in its objective function and its set of constraints has been chosen as a starting point. The rational for this choice is that agricultural production in the watershed involves numerous intermediate activities and requires that each activity be completed prior to the next one. The intermediate activities often compete for available resources. For example, ploughing precedes planting whereas planting precedes weeding among others and each has a bearing on the other not only in terms of increasing/decreasing its efficacy on productivity but also in terms of resource competition including the meager household finances and labor. The two season production in the tropics further entrenches this scenario. For example, land preparation for a particular crop could be done during harvesting period of another leading to competition for the resources labor.

Furthermore, crop rotations become shorter given smaller land sizes and limited opportunity for fallowing. Consequently, sequencing of crops of different species becomes apparent in this situation, such a situation can be handled by using sequential models. Sequencing models insure that the predecessor activities are completed before the successor activities can begin. Households are assumed to maximize their gross margins and this is considered as the objective function for the optimization problem. Whereas, other important factors such as resource endowments, technology options, socio-economic conditions, and climate change scenarios, adaptation strategies and bio-physical and environmental sustainability criteria are integrated into the constraints.

The development of the bio-economic model capturing the agricultural production system in the watershed is being carried out using technical, economic, and environmental data gathered by GARC and ARARI during the previous five years.

Calibration and validation of the model will be carried before being used for social, economic, policy, institutional, and technological simulations. This an important step to ensure fitness of the model to the real situation. It consists of comparing the base period simulated outcomes (for different contrasting years) to real data from years with corresponding weather conditions. The procedure of calibration will start by integrating basic data on climate, soil, crop parameters, and crop management techniques into the biophysical model. For each crop, the model will be run for five consecutive periods, and annual simulated yields will be collected and compared with the farm's annual observed yields over the last five years. If the simulation results are close to observed data, then the model will be considered as fit to the farm environment and can be used for simulations other new scenarios.

So far the base farm-household model has been developed using the General Algebraic Modeling Systems (GAMS). The base model was extended by including main and second cropping and also irrigation season and it was checked by including selected crops such as sorghum, teff, wheat, barley, chick pea, garlic, finger millet and lentil. The model will be further extended by including household typologies, livestock, inter cropping and double cropping, risk and nonlinearity.

Another dimension of the bio-economic modelling work is one of how the watershed is treated. The first and more realistic approach starts from establishing different farm household typologies, modeling a typical farm household in each typology and combine all of them by using the number of households in the watershed that fall into each of the typologies as weights. This model will try and capture the interactions between farm households including all the positive and negative externalities amongst them as each individual household tries to maximize its own benefits regardless of its effects on others. The second modeling approach will pretend as if the entire watershed belongs to a single benevolent decision maker who will optimize in such a way that the total benefit for the whole watershed will be maximized. Parameters for the second model will be driven from the calibrated and validated household model from the first approach. Once the two types of models are developed, calibrated and validated, realistically possible set of scenarios will be developed by the researchers from ICARDA, GARC, ARARI, staff of the local and district level department of agriculture and more importantly representative farmers from each farm household typologies. Then simulations will be conducted for the different scenarios and comparisons made. The difference in the results (if any) between the two types of watershed level models will be a measure of efficiency gains/losses due to conflict of interest among the different agents (particularly farmers). If the losses are found to be high, then one of the policy implications will be that consolidation of land or creating producers and/or marketing cooperatives might be a feasible option to maximize net social benefits and possibly to reduce the negative impacts of climate change.

The ultimate goal of the bio-economic modeling exercise is to provide insight on the effects of various technological, policy, institutional, environmental, biophysical, and marketing interventions on farmers' livelihoods and help decision makers by identifying the optimal courses of action for achieving the desired outcomes (including poverty reduction, food security and sustainability) at both the system and sub system levels..

***NOTE**: The data presented in this report are currently being elaborated for scientific publication, thus some of them are not final. The aim of this report is to summarize the nature and quality of the activities conducted and of the dataset generated, and to illustrate the main results obtained.*

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