Faso Kaba Seed Enterprise. Adoption of solar-powered irrigation pumps in combination with efficient irrigation methods by a seed company in Mali. The adoption by seed companies stimulates the adoption by vegetable farmers.

(Photo: World Vegetable Center)

Feed the Future Innovation Lab for Small Scale Irrigation

ANNUAL REPORT *Mali*: October 1st, 2021 - September 30, 2022

Submitted by the Norman Borlaug Institute for International Agriculture and Development, The Texas A&M University System & AgriLife Research

Partners in Mali: International Food Policy Research Institute (IFPRI); International Water Management Institute (IWMI); World Vegetable Center; Ecotech; EMICOM

1. Introduction

The Feed the Future Innovation Lab for Small Scale Irrigation (ILSSI) is a cooperative agreement led by the Borlaug Institute for International Agriculture Development (BIIAD) at Texas A & M University (TAMU). Activities in Mali are primarily supported through a buy-in by Bureau for Humanitarian Assistance and some central funds. This report describes progress toward objectives in fiscal year 2022; the project ends August 11, 2023. In Mali, the project has sub-awards with the International Water Management Institute, International Food Policy Research Institute, World Vegetable Center, EMICOM and EcoTech. In addition, we have a leveraged project under Sene Yiriwa.

2. Issues, Concerns, and Lessons from the reporting period

Issues and concerns

Irrigated production continues to increase by farmers with equipment suppliers and associated services expanding market sales to try to meet demand. Despite weak market integration, relatively limited private and financial sector capacity, and continued insecurity and sanctions, access to equipment and services is increasing. Companies are beginning to offer consumer finance and PAYGO options. However, approaches are needed to lower pump and equipment costs for the poorest farmers to adapt to climate change and to meet demand for produce. Farmers need to invest their own resources in labor-saving, water lifting and field equipment, especially as climate change has increased the need for supplemental and dry season irrigation across crops.

Areas requiring further investment

Poorest smallholders need interventions to be able to invest in irrigation, but it is unclear which approaches to reduce prices are good practice and which might undermine the market. Development partners are implementing various approaches to reduce costs for solar and other pumps to farmers, including finance to different actors and pump subsidies (e.g., Togo). Anecdotal evidence suggests public subsidy schemes benefit high income farmers and exclude women. Analysis is needed across the region on what is effective to reach poor smallholders without disrupting markets.

Planning, monitoring and managing water in agriculture at different scales is needed to support sustainability. Given the lack of plans, monitoring and regulation for smallholders with dispersed, self supply systems, potential water scarcity and pollution increases. Community approaches and capacity strengthening in water governance is needed, especially in high-risk watersheds, until government capacity increases.

Skilled, human resource pipeline for private and public sectors will be critical to the expansion of the market in irrigated agriculture and in particular, sustainability (regulatory and planning). Private companies will likely be expected to self-regulate in the water sector for business sustainability, but lack of skilled staff already constrains private company growth, even without tasks related to self-regulation. At the same time, tertiary education institutions are not developing a human resource pipeline. Investment is needed to expand and upgrade capacity.

Supportive intersectoral water policies and institutions. Continued policy support is important to align national goals in agriculture, especially horticulture, with nutrition, climate, and water, within a suitable institutional framework. ILSSI continues policy related work on horticulture, but this needs to be shared at higher levels of decision-making.

3. Progress toward research objectives

Objective 1: Identify and test approaches to sustainably scale SSI through reducing constraints and strengthening opportunities for access

Upscaling resilient small scale irrigation systems

Private sector partner activities include:

1. Adapting marketing, distribution, and finance, approaches to reach women and youth
2. Testing more business models and finance modalities to reach different market segments
3. Adapting credit scoring tools to contextual factors and to be more gender sensitive
4. Companies taking on extension, financial education and marketing roles, e.g. educating farmers on financial literacy and agronomy, for client acquisition and reduced risk of default
5. Identifying demand for mixed uses, e.g fruits, vegetables, poultry, livestock/dairy, fish farming
6. Renegotiating terms with financial services (EMICOM and BNDA)

Constraints include:

- EMICOM ramped up marketing and the distribution network. Despite agreement with Angaza and BNDA, multiple crises reduced access to credit and increased interest rates.
- High demand by the youth was constrained by family elders who decide on assets, investments; marketing strategy is being adapted to also target information toward elders
- Cotton sanctions reduced farmers income and farmers could not complete pre-orders
- Political insecurity and sanctions affected shipments and reduced distribution in insecure areas
- EcoTech's SPIS shipment was refused entry (sanctions); the company had to reorder/reship
- High costs of inputs: High fertilizer cost reduced ability of farmers to invest in pumps; high fuel prices reduced ability of farmers to operate fossil fuel pumps
- Increased financial risk decreased distributors' willingness to provide farmer credit
- Market position of farmers: Output markets are available, but low bargaining power with buyers reduces net profits and in turn, farmer ability to make down payments and PAYGO payments
- High costs of navigating tax exemptions and access to foreign exchange
- Lack of cellular network coverage disrupts mobile money payment, PAYGO pump control

Overcoming constraints to scaling for resilient SSI market systems

Ensuring local, context specific marketing and technology system selection

IFPRI found that locale-specific targeting of small-scale irrigation technologies is essential to scaling, with plot level specific advice and technologies for water and land management (see: Hierarchical modelling of the constraints to irrigation adoption in Ghana, Ethiopia, and Tanzania).

Analyzed market structure and margin along different points of SSI chain of actors

IMWI analyzed the market for solar-powered irrigation system (SPIS) equipment and services in Mali, finding the dynamics of solar-based irrigation equipment supply chain and market characterized by:

- High popularity/availability of solar home products can increase awareness/uptake of SPIS.
- Prices for solar panels and SPIS are falling. On average, a secondhand, 250-Watt panel costs between 40,000 - 50,000 CFA (~ USD$70-85) [1-3 panels of are needed for the desired water flow]. Locally produced panels cost around 90,000 CFA; quality is comparable.

- Grundfos (Denmark) and Lorentz (Germany) dominate high-quality pump market (fossil fuel and electric), while Chinese brands dominate other segments. Grundfos and Lorentz pumps cost around 1 million CFA and last 10+ years. Chinese pumps are half or quarter of the price, but many farmers replace every 2 years.
- Local assembly of pumps is done by local technicians from used parts from imported pumps; this reduces quality and undermines market strength for high quality products.
- In Mali's long supply chains, local technicians link pump suppliers and farmers. However, advice is intended to maximize the technicians' profit, and not provide farmers with suitable equipment.
- With a limited number of their own technicians on staff, companies rely on independent technicians to send potential customers their way.
- Some farmers have lost money on low quality irrigation equipment or misuse with low level of technical knowledge and experience. This discourages other farmers from investing.

Support for business model and finance/credit modalities for scaling inclusively

IWMI organized the workshop 'Solutions supporting partnership to scaling small scale irrigation in Sub-Saharan Africa' (15 participants) with EMICOM, EcoTech, and technical staff from the Ministry of Agriculture; co-organized demand-supply linkage workshops in Sikasso. The demand-supply linkage workshops and field demonstrations facilitate market linkages within the supply chain, between solar irrigation pump suppliers and related services and suppliers (borehole, pipe/sprinkler suppliers); and between suppliers and farmers.

Identified entry points for the improved diffusion of small scale irrigation

IFPRI published "Smallholder irrigation technology diffusion in Mali: Insights from stakeholder mapping" based on workshops at national and regional levels. Key constraints identified: lack of linkages between intermediary organizations in the small-scale irrigation diffusion process, such as commodity associations, financial institutions and technology vendors with government agencies in charge of irrigation, limiting the sharing of consistent and effective information across entities; the lack of a clear policy framework and long-term guidance for private individual irrigation; an associated lack of targeted technology development including limited adaptation to different local contexts, missing financial products linked to irrigation technology, and inadequate capacity building of farmers through extension services and demonstration sites. Workshop participants suggested a dedicated platform for effective information exchange, improved capacity on private-led irrigation, and a supportive policy and financial environment to ensure growth with sustainability.

Following from the recommended information platform, IWMI initiated a multi-stakeholder dialogue; this is found to be effective to increase market integration and resilience in other countries. As reported in 'Multi-Stakeholder Platforms and Processes: The Case for Inclusive and Sustainable Agricultural Water Management in Mali', participants also noted little engagement between public and private sector and other barriers to scaling agricultural water management, e.g. finance.

Objective 2: Identify and test approaches to scale SSI to be sustainable and support resilience

Identifying cropping systems that provide the best productivity under different climatic scenarios

Vegetables in Inner Niger Delta and Mali: Identifying suitable land for vegetable and other crop production is important to ensuring the sustainability of the water resources and agricultural sectors to support the effort toward alleviating malnutrition in Mali. TAMU's IDSS team assessed the impact of land use change and irrigation expansion on water balance components and inflow to the Inner Niger Delta.

The result revealed the impacts of the land use change on the water balance components, particularly in the central and southern parts: increased surface runoff and drainage water with expansion in irrigation. These results highlight the need for an integral approach to develop well-planned land use management practices in the basin.

An ex-ante analysis on conservation practices using the SWAT model (i.e., contour farming, strip cropping, and grasses waterway) examined potential for improvement at subbasin scale. Analysis showed that conservation practices had no significant change on the water balance components at the basin scale but potential improvement in reducing the soil erosion and enhanced water availability for the vegetable production. Notably, water use efficiency would improve if large water consuming crops (especially rice) were replaced by vegetables.

Results of the Crop Water Requirement (CWR) and Irrigation Water Requirement (IWR) analysis show that for optimal yield, supplementary irrigation is necessary for vegetable production in Mopti region. Water requirement for melon was the highest (900 mm/season) followed by shallot (866 mm/season) and then tomatoes (839 mm/season). Okra had the least water requirement (390 mm/season). In addition to the rainfall, all five vegetables require irrigation to reach optimal yield. Tomato, shallot, chili and melon require over 500 mm of irrigation based on the planting dates indicated by farmers in Mali. Okra, on the other hand, requires about 120 mm of irrigation per season. See Annex 2 for more results.

Irrigation and water pollution analysis

IFPRI research shows that fertilizer and purchased seed use is higher in irrigated plots by about 12% compared to rainfed alone, i.e. clear impact of irrigation on input complementarity. However, irrigated intensification will contribute to water pollution from agro-chemicals without proper management. ILSSI developed training materials for farmers on safe pesticide use, shared with Sene Yiriwa and private company partners (in French).

Assess the potential for innovative technology and scheduling tools to contribute to social-ecological resilience

Estimated potential of solar pumps in improving irrigation access vis a vis energy intensity

IFPRI analysis on the impact of climate change on the cost-effectiveness of solar irrigation relative to diesel irrigation shows that climate change supports further adoption of solar as compared to diesel as water scarcity grows the need for lifting groundwater from greater depths and also increases crop water demands. Climate change improves on the cost-effectiveness of solar irrigation relative to diesel irrigation. The competitive edge of solar irrigation is growing further with climate change, as a result of complex interactions across higher solar irradiation levels, increased crop water demands and higher temperatures (the latter of which can negatively affect solar system performance). This higher economic viability of solar over diesel pumps is irrespective of the food-security enhancing climate mitigation benefits of these systems. *IFPRI presented the results at the African Water and Sanitation Week, Stockholm World Water Week and ILSSI-USAID World Water Day virtual event.*

Identify pathways from water access and management to improved water and food security, and sustainable resilience (Mali)

The World Vegetable Center research has described the context of how small scale irrigation can contribute increased production of quality vegetable seed and fresh vegetables. WorldVeg is combining results into a strategy to inform policy making in FY2023.

Objective 3: Identifying and testing approaches to maximize inclusivity, effective governance, women's empowerment, and involvement of youth for nutrition-sensitive irrigated production

Gender sensitive business models and scaling, aligned with private partners

Despite the co-development of a gender-responsive credit/customer assessment scorecard with the private companies, individual sales agents act on bias in client acquisition: agents perceive women as unlikely to qualify for credit, and therefore do not pursue pre-sales assessments. EcoTech is piloting sales models that are community-based and engage women as sales agents; results indicate that the structure of the marketing approach can be changed to improve sales to women.

In addition, youth are blocked by elder family members from purchasing pumps on PAYGO and asset-based finance arrangements; EMICOM is expanding its outreach to include family elders as decision-makers.

4. Future work

ILSSI closes August 2023; the project will not be extended at end of 10 years. Final activities include:

Research and scaling

- Close out scaling partnerships with private sector partners
- Complete research on irrigation-nutrition linkages
- Complete field research on farmer perceptions and use of solar irrigation

Outreach and engagement

- Workshop on national strategy for irrigated horticulture production (date TBD)
- Demand-supply linkage and demonstration workshops with EMICOM
- Multi-stakeholder dialogue platform/workshop (date TBD)
- Outreach to Horticulture Innovation Lab activities as relevant

Annex 1. Data and publications

Datasets

1. Dembélé, Siaka; Tignegre, Jean-Baptiste; Diarra, Ba Germain, 2021, Qualitative data on irrigated vegetable seed sector development, World Vegetable Center

Publications

Peer-reviewed publications

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International Water Management Institute (IWMI). 2021. Evaluation du potentiel d'expansion durable de l'irrigation solaire à petite échelle à Ségou et Sikasso, Mali. Colombo, Sri Lanka: International Water Management Institute (IWMI). 8p.

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Capacity development material or product

Innovation Lab for Small Scale Irrigation (2022). Guide to Safe and Effective Use of Chemicals for Crop Production. French and English versions.

International Food Policy Research Institute (2021). Pathways to more nutrition-sensitive irrigation. IFPRI Video. French and English Versions.

Annex 2. Impacts of land use change and irrigation expansions land suitability analysis for Upper Niger River Basin

The Upper Niger River (UNR) basin covers 276,000 sq km upstream of the Inland Niger Delta (IND). The Niger and Bani are the two main rivers contributing the total inflow to the IND and the downstream parts. These two rivers confluence at Mopti, just upstream of the inlet of IND. Anthropogenic activities and other natural drivers have an immense impact on water management and use, affecting the ecosystem and wetland hydrology. Population growth increased water demand, and there are increased efforts and interest to achieve food security through employing water resources development programs upstream of the IND. A tradeoff between water resource development and water use is crucial to mitigate water shortages and impacts on the downstream ecosystems. Unless an equitable water use approach is adopted, conflicts between the upstream and downstream water users will be inevitable. In addition, an integrated approach between the development and utilization of water resources and environmental flow release can trigger more efficient water use to minimize the vulnerability of the wetland and risks to its ecosystem. The available evidence indicates that the flood inundation area of the IND has reduced due to several interplaying factors, mainly land use and climate change, poor water management, and expansion of upstream mega irrigation development (Rebelo et al., 2013). The impacts are becoming more intense due to climate change and will continue to do so with projected population increase. Proper water management practices and knowledge of water resources are crucial for the sustainability of water resources and wetland ecosystems.

According to the U.S Geological Survey (USGS) report, cropland has predominately increased by 3.5% annually across the south, especially in Haut Bani Niger, Koutiala Plateau, and Kaarta ecoregions. The expansion of the cropland was attributed to the need to feed the fast-growing population and to grant food self-sufficiency. In addition, the irrigation land has increased by 400% in the southwest and along the Niger River and its tributaries in the southern part of the IND. Despite the considerable year-to-year variation of the flood extent in the IND, no significant land use change has occurred except for irrigation interventions in some parts. Conversely, there is a 23% decrease in the gallery forest due to agricultural expansion driven by an increase in population and other factors, which induced the destruction of the natural habitat, which is one of the core issues in Mali. The reduction in forestland instigates severe erosion of the topsoil, which adversely reduces soil fertility and land productivity. The eroded soil eventually deposited upstream reservoir area. This potentially reduces the overall efficiency and lifetime of the hydraulic structures unless extensive soil water conservation interventions are implemented to minimize soil erosion. More studies are required to assess the land use dynamics and irrigation expansion to quantify the subsequent impacts on the water balance. Therefore, evaluating the impacts of land use and irrigation expansions upstream of the IND is crucial for better management and sustainability of the water resources and the ecosystems in the IND and the basin at large.

Since there is pronounced expansion in agricultural land across the basin, identifying suitable land for vegetable and other crop production is paramount to ensuring the sustainability of the water resources and agricultural sectors to support the effort toward alleviating malnutrition in Mali. The available statistics indicate that 29 percent of Mali's population is already malnourished. Biophysical and socio-economic variables such as climate, soil, land use and topography, population density, and market proximity are key indicators and inputs for land suitability analysis. Integrating expert opinion and farmers' feedback is also essential to enhance the accuracy in identifying suitable land for better production. Augmenting traditional agricultural practices, commonly used in Mali, with climate-smart and conservation agriculture can benefit farmers and pastoralists by boosting agricultural productivity and household-level income, eventually helping the growth of the Gross Domestic Product (GDP) of Mali. The climate-smart agricultural practices include systems that conserve soil moisture, reduce greenhouse gas emissions, sequester carbon, and enhance ecosystem productivity (Lipper et al., 2014; McCarthy et al., 2011; Steenwerth et al., 2014; Zerssa et al., 2021; Zougmoré et al., 2016). Therefore, identifying potential environmentally and economically sustainable climate-smart agricultural management is crucial to enhance nutrition-sensitive irrigated production.

This study assessed the impact assessment of land use change and irrigation expansions on the different water balance components and inflow to the IND. It also included land suitability analysis for vegetable (okra, chili, tomato, shallot and melon) production across the Malian part of basin, as well as crop water requirement and irrigation water requirement of the selected vegetables in Mopti region. The land suitability assessment was conducted using a GIS-based Multi-Criteria (MCE) technique. Selected biophysical (climate, soil, land-use and slope) and socioeconomic (proximity to road and population density) factors were weighted by experts using a pair-wise comparison matrix, reclassified and overlaid to identify the suitable areas for vegetable cultivation. The crop water requirements and irrigation water requirements of the vegetables were assessed using the CROPWAT 8 computer model. The impact assessment of land use change and irrigation expansion (biophysical modeling approach) was implemented to simulate crucial hydrological fluxes for the baseline periods from 1982 to 2020. The SWAT model was used to develop the baseline model. This model requires several hydroclimatic and biophysical input variables acquired from different sources, mainly from satellite products, given the high purchasing cost of the observed climate data from the National Meteorological Agency (MALI-METEO) of Mali. After developing the baseline model, impacts of land use change and irrigation expansions were integrated into the model. Then, changes in the water balance components were quantified to assess the overall impacts on the IND and other parts of the basin. In addition, scenarios of climate-smart agricultural interventions were implemented in highly suitable areas, and their biophysical impact was estimated using the calibrated and validated SWAT model. This component is also valid for identifying environmentally sustainable approaches for improved nutrition and women empowerment through small-scale irrigation interventions to enhance high-nutrition crop and fodder production locally in the IND.

After obtaining the optimal model simulation through calibrating the sensitive model parameters, a separate model simulation was carried out using the 2020, 2010, and 2000 land use maps by keeping all other parameters constant. Thus, the changes in different water balance components are due to the change in land use. The subbasin level model outputs of actual ET, soil water, water yield, and sediment yield were generated, and the change in these water balance components was investigated under the three land use inputs. Since there was no significant change in land use in 2020 and 2010, the changes in the water balance components were not pronounced as well, and the result obtained due to land use change in 2020 and 2000 is presented in this section. Figure A.1 below, illustrates the spatial distributions of change in actual ET, soil water, water yield, and sediment yield simulated using different land use as the main input. A reduction in actual ET up to 54mm has been observed in subbasins mainly located in the central and southern parts of the watershed due to land use change in the past two decades. Croplands are the dominant land use types in these subbasins. Except for some subbasins in the southwest parts, there is no significant change observed in the soil moisture due to land use change. Similarly, the subbasins in the central and southern areas depict an increase in water yield from 11-35mm, except one subbasin in the southeast that revealed a decline in the water yield by 10 to 20mm. The water yield accounts for both surface and groundwater, and its enhancement might be due to land use change induced surface runoff increase and also an increase in drainage water because of the expansion in irrigation. The change in sediment yield to the range of ±20t.ha^{-1}yr^{-1} has been observed in the majority of the subbasins across the watershed. Pronounced decline and enhancement in sediment yield has been identified in the subbasin in the central parts of the basin. The results from this study revealed the impacts of the land use change on the water balance components particularly in the central and southern parts. This may highlight the need for an integral approach to develop well-planned land use managed practices in the basin.

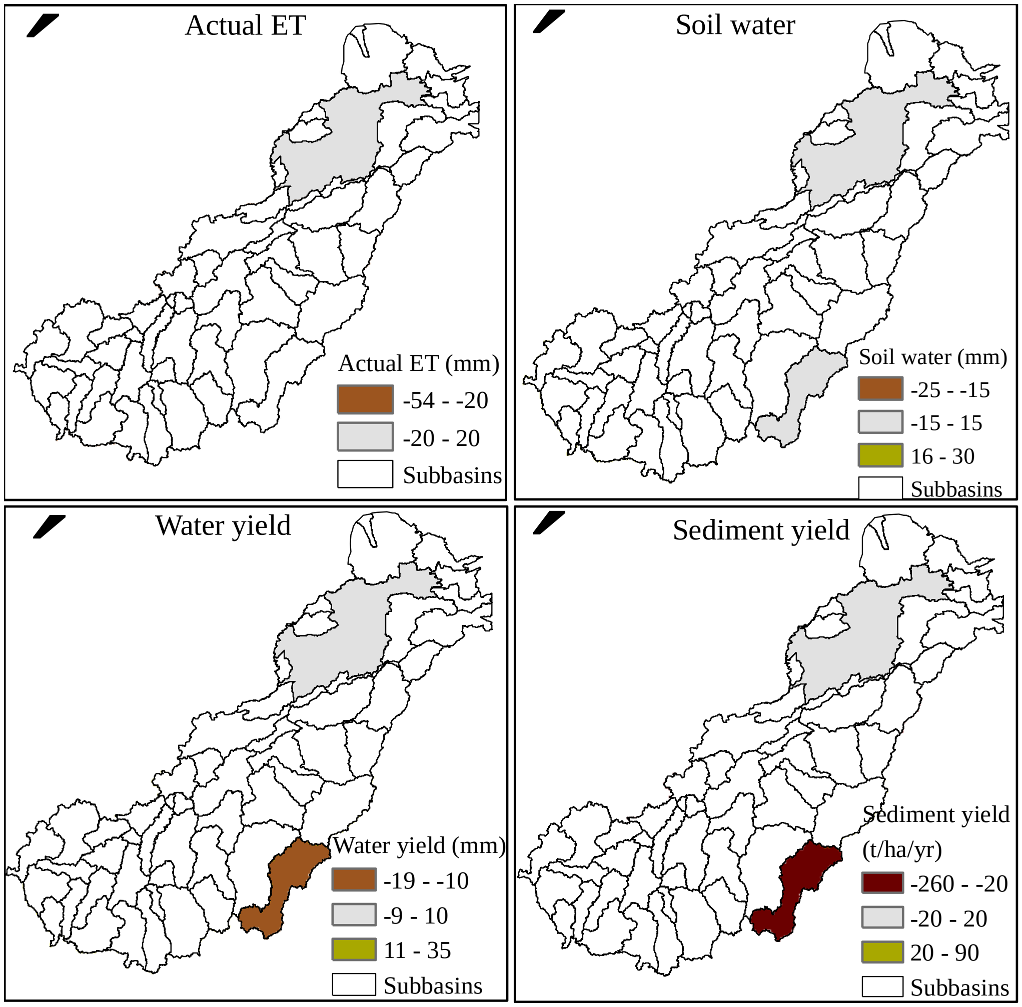

Figure A.1: Biophysical model simulation of the different water balance components under the three land use change scenarios.

The land suitability assessment for vegetable production, extracted at a threshold level greater than 80 % and excluding all restricted areas indicate that ~38 % of the study areas are highly suitable for producing melon, followed by okra and chili (29 %), tomato (20 %), and shallot (10 %) (Figure A.2. a, b, c, d, and e).

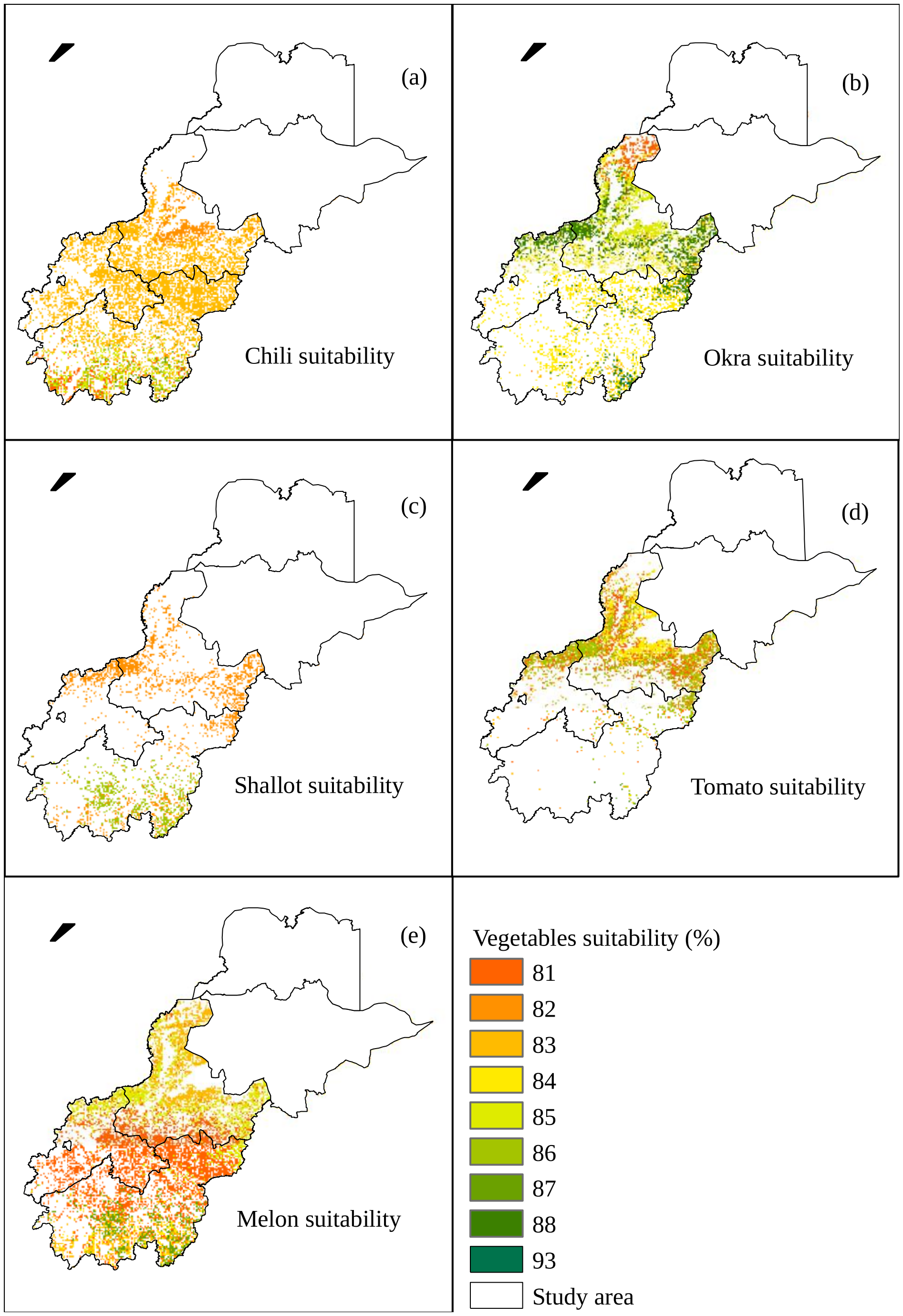

Figure A.2: Potential suitability maps for vegetable production in Mali: optimal suitable land (greater than 80 %) for Chili (a), Okra (b), Shallot (c), Tomato (d), Melon (e) productions.

Following the aggregation of the different vegetables at a suitability level greater than 85%, (Figure A.3) watershed discretization using the SWAT model indicted that the suitable lands for vegetable production are mainly located in the central parts of the basin (i.e., subbasins 34, 41, 45 and 46) and close to the IND (subbasins: 9, 16, 17, 19, 20, 22, 23, and 26). To identify the suitable areas that all the vegetables cover in the basin, the individual suitable maps wer aggregated at a suitability level greater than 85% (Figure A.3). Based on the resulting watershed discretization using SWAT model, the suitable lands are mainly located in the central parts (i.e., subbasins 34, 41, 45 and 46) and close to the IND (subbasins: 9, 16, 17, 19, 20, 22, 23, and 26).

Regardless of the current agricultural conservation practices that are existing on the ground, the conservation practices introduced into the SWAT model (i.e., contour farming, strip cropping, and grasses waterway) illustrate that there is potential for some improvement at subbasin scale. There is no significant change on the water balance components at the basin scale analysis. The analyzed conservation practices suggest this could be effective in reducing the soil erosion and enhanced water availability for the vegetable production. The water use efficiency would improve if large water consuming crops (e.g., rice) were replaced by vegetables.

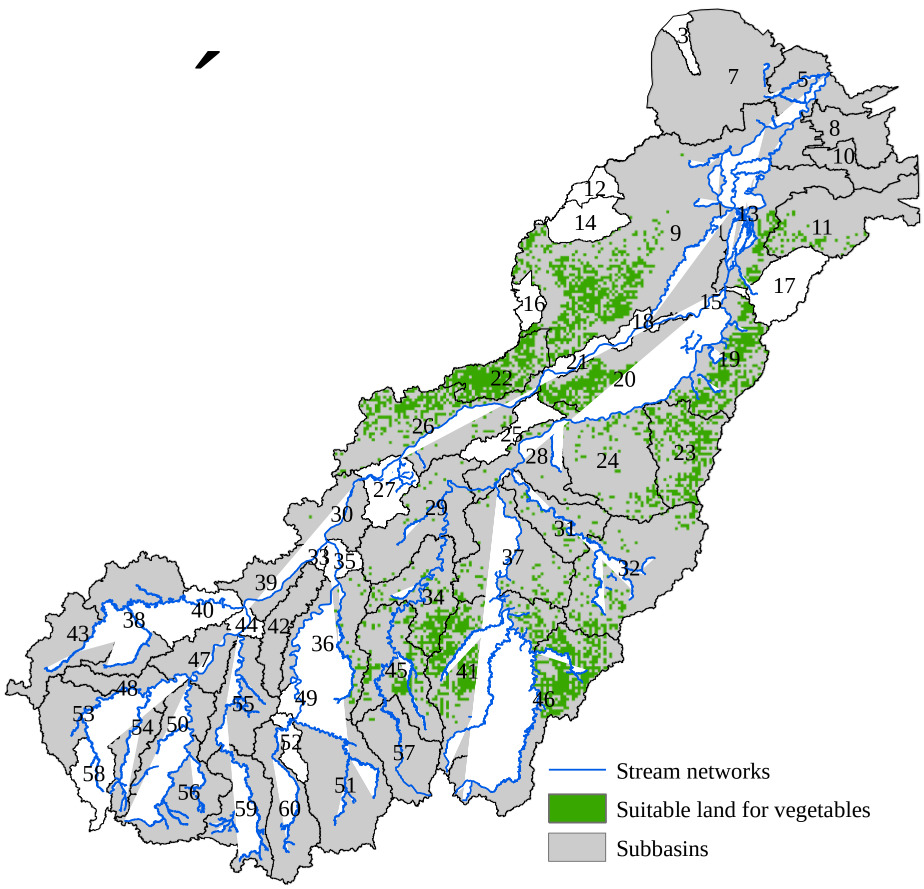

Figure A.3: Suitable land for vegetables (i.e., Chili, Melon, Okra, Shallot and tomato) in the central and downstream sparts of the basin.

Results of the CWR and Irrigation Water Requirement (IR) analysis shows that for optimal yield, supplementary irrigation is necessary for vegetable production in Mopti region (Figure A.4). Water requirement for melon was the highest (900 mm/season) followed by shallot (866 mm/season) and then tomatoes (839 mm/season). Okra had the least water requirement (390 mm/season). In addition to the rainfall, all the five vegetables require irrigation if optimal yield is desired. Tomato, shallot, chili and melon require over 500 mm of irrigation based on the planting dates indicated by farmers in Mali. Okra, on the other hand, requires about 120 mm of irrigation per season.

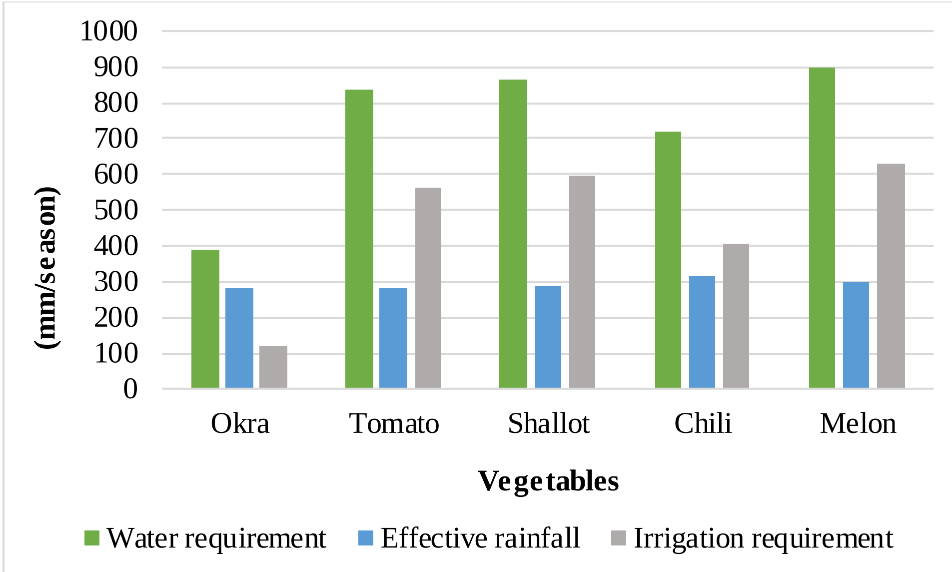

Figure A.4: Water requirement, effective rainfall and irrigation requirement of the vegetables in Mpoti

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