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SECTOR ENVIRONMENTAL GUIDELINE: CROP PRODUCTION

MARCH 2019

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SECTOR ENVIRONMENTAL GUIDELINE: CROP PRODUCTION

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DISCLAIMER

ACRONYMS

A/COR	Agreement/Contracting Officer's Representative
ADS	Automated Directives System
BEO	Bureau Environmental Officer
Bt	*Bacillus thuringiensis* (Cotton)
CBNRM	Community Based Natural Resource Management
CFR	Code of [US] Federal Regulations
CO_2	Carbon Dioxide
CSA	Climate-smart Agriculture
CP	Crop Production
EA	Environmental Assessment
EHS	Environment, Health, and Safety
EIA	Environmental Impact Assessment
EMMP	Environmental Mitigation and Monitoring Plan
EPA	US Environmental Protection Agency
ESDM	Environmentally Sound Design and Management
ESIA	Environmental and Social Impact Assessment
FAO	Food and Agriculture Organization of the United Nations
FIFRA	Federal Insecticide, Fungicide and Rodenticide Act
GAP	Good Agricultural Practices
GEMS	[USAID] Global Environmental Management Support Project
GFSS	Global Food Security Strategy
GHG	Greenhouse Gas
GHP	Good Handling Practices
GE	Genetically Engineered

GM	Genetically Modified
IP	Implementing Partner
IPM	Integrated Pest Management
ISFM	Integrated Soil Fertility Management
ISO	International Organization for Standardization
ISF	Integrated Soil Fertility
K	Potassium
LOP	Life-of-Project
MEA	Millennium Ecosystem Assessment
MEO	Mission Environmental Officer
MRL	Maximum Residue Limit
MSMEs	Micro, Small and Medium Enterprises
N	Nitrogen
NGO	Non-Governmental Organization
NICS	Nature's International Certification Services
NRM	Natural Resource Management
OPV	Open-pollinated Variety
P	Phosphorus
PEA	Programmatic Environmental Assessment
PERSUAP	Pesticide Evaluation Report and Safer Use Action Plan
PIP	Plant-Incorporated Protectants
PPE	Personal Protective Equipment
R&D	Research and Development
REA	Regional Environmental Advisor
RECP	Resource-efficient and Cleaner Production

SDO	Standards Development Organization
SEG	Sector Environmental Guideline
SOP	Standard Operating Procedures
TEEB	The Economics of Ecosystems and Biodiversity
TRIPS	Trade-Related Aspects of Intellectual Property Rights
UNEP	United Nations Environment Programme
USAID	United States Agency for International Development
USDA	United States Department of Agriculture
WHO	World Health Organization
WTO	World Trade Organization
WUA	Water User Association

TABLE OF CONTENTS

TABLE OF FIGURES

TABLE OF TABLES

TABLE OF BOXES

PREFACE: ABOUT THIS DOCUMENT AND THE SECTOR ENVIRONMENTAL GUIDELINES

This document presents one sector of the *Sector Environmental Guidelines (SEGs)* prepared for the United States Agency for International Development (USAID) under the Agency's Global Environmental Management Support Project (GEMS II). It covers the Agricultural Crop Production Sector.

For the purposes of this document, crop production is defined as the branch of agriculture that deals with growing crops for use as food, fiber, feed, and fuel.

All SEGs are accessible at: www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/sector-environmental-guidelines-resources.

OBJECTIVES

Consistent with the entire SEG series, the purpose of this Crop Production SEG is to support Environmentally Sound Design and Management (ESDM) of crop production activities commonly supported by USAID in efforts to reduce poverty, increase resilience, and improve nutrition. ESDM means that activities are appropriate for the environmental context, resilient to foreseeable changes in this environment, and designed and implemented to minimize adverse impacts on the environment, health and communities—and to maximize environmental co-benefits, when consistent with their primary objective. This SEG supports ESDM by providing plain-language information regarding:

- The environmental and social context of the crop production sector;
- The potential environmental and social impacts of crop production actions supported by USAID;
- Measures for preventing or otherwise mitigating adverse social and environmental impacts of crop production activities, both through sound design and by integrating environmental and social mitigation measures into implementation;
- Measures for minimizing vulnerability of activities to climate change; and
- More detailed resources for further exploration of these issues.

AUDIENCE

This SEG is intended mainly for USAID Agreement and Contracting Officers' Representatives (A/CORs), USAID Mission, Regional and Bureau Environmental Officers and Advisors (MEO/REA/BEOs), Agricultural Officers, and implementing partner (IP) staff engaged in implementation of crop production programs, activities and actions.

However, this SEG, like the entire SEG series, is not specific to USAID's environmental procedures. SEGs are written generally and are intended to support ESDM of crop production by all actors.

> ***Note:*** *No SEG is a substitute for detailed sources of technical information or design manuals. Users are expected to refer to listed references and resources for additional information.*

ENVIRONMENTAL COMPLIANCE APPLICATIONS AND ADVISORY

USAID's mandatory life-of-project (LOP) environmental procedures require that the potential adverse impacts of USAID-funded and managed activities be assessed prior to implementation via the Environmental Impact Assessment (EIA) process defined by 22 CFR 216 (Reg. 216). They also require that the environmental management/mitigation measures ("conditions") identified by this process be written into award documents, implemented over LOP, and monitored for compliance and sufficiency.

The Reg. 216 process as implemented by USAID's mandatory operating policies (Automated Directives System or ADS), is USAID's principal mechanism to ensure ESDM of USAID-funded activities—and thus to protect environmental resources, ecosystems, and the health and livelihoods of beneficiaries and other groups. USAID's environmental procedures strengthen development outcomes and promote the mission of USAID.

This Crop Production SEG directly supports environmental compliance by providing information useful for assessing the potential environmental and social impacts of programs, projects, actions and activities, and identifying and designing appropriate related mitigation and monitoring measures.

> ***Advisory**. This Crop Production SEG, like the entire SEG series, is advisory only and not official USAID regulatory guidance or policy. Following the practices and approaches outlined herein does not necessarily assure compliance with USAID Environmental Procedures or host country environmental requirements.*

DOCUMENT STRUCTURE

This Crop Production SEG is comprised of five main sections (A–E), and one Annex addressing irrigation.

Section A: Crop Production Sector Description briefly describes the crop production sector with focus on those elements most relevant to environmental and social impacts and their mitigation.

Section B: Quick Reference Guide. This section summarizes the impacts and mitigation measures presented in sections B and C, respectively. Cross references to the discussion of these issues in the main text is provided.

Section C: Potential Environmental Impacts of Crop Production describes potential impacts—whether direct or indirect--of the crop production actions commonly supported by USAID. These actions are categorized as follows, with each category addressed in a separate subsection:

- Crop production itself
- Developing and strengthening the crop production enabling environment
- Building crop production infrastructure
- Supporting inputs to crop production
- Supporting crop production research and innovation
- Supporting mixed farming systems and agroforestry
- Supporting harvest and post-harvest storage, processing, and marketing

- Integrating crop production with nutrition; disaster risk reduction; micro, small and medium enterprise (MSME) support, disaster risk management and natural resource management (NRM) programming

The section concludes with a cross-cutting discussion of the social impacts of crop production.

Section D: Mitigation Recommendations, Including Design Measures provides general and sometimes specific mitigation measures for mitigating the adverse impacts described in Section C. Its organization parallels that of section C.

Section E: Resources and References provides a linked bibliography for further learning.

Annex I: Irrigation addresses irrigation as one of the inputs of production. Historically, irrigation has been an important agricultural technology with strong impact on crop productivity—and often with significant environmental impacts.

Note regarding cross-references: Users of this document engaged in any or a combination of crop production actions can focus directly on the relevant section that covers issues of interest. However, crop production activities and their impacts are by nature interconnected. For example, use of fertilizers is relevant to soil improvement, but misuse is an important source of pollution. The text provides hyperlinked cross-references where issues are cross-cutting.

SCOPE AND LIMITATIONS

This document is the result of a comprehensive technical update undertaken in 2018–2019. It addresses only Crop Production. The SEG series contains separate documents on multiple other agricultural sectors, including livestock, dryland agriculture, and forestry. Hyperlinks are included where these SEGs are referenced in the text.

COMMENTS AND CORRECTIONS

Each SEG document is a work in progress. Comments, corrections, and suggested additions are welcome. Please provide feedback via link at www.usaid.gov/environmental-procedures/sectoral-environmental-social-best-practices/sector-environmental-guidelines-resources.

A. CROP PRODUCTION: SECTOR DESCRIPTION

Crop production is the branch of agriculture that deals with growing crops for use as food, fiber, feed and fuel. Crop production encompasses or intersects with soil management, pest management, food safety, harvesting and post-harvesting, food processing, irrigation, crop science, plant breeding, genetics, farm management and marketing, agricultural laws and regulations, mechanization, and natural resource management (NRM), among others.

This section briefly describes crop production in USAID programming and the set of concepts, principles and basic "operating rules" for crop production systems that are most implicated in the environmental and social impacts of the sector, and in decision-making to address these impacts. It thus provides essential context to Section C (Impacts) and Section D (Mitigation).

All users of this document are assumed to have significant expertise in one or more key aspects of crop production and/or environmental management, but few will have equal depth of knowledge in all aspects of the sector. Users are encouraged to read the portions of this section that are helpful to supplement their professional knowledge.

A.1 CROP PRODUCTION IN USAID PROGRAMMING

Programming across the crop production value chain to address hunger, malnutrition, and poverty has been and remains a core focus for USAID. USAID:

- **Leads the U.S. Government's global hunger and food security initiative, Feed the Future,** in collaboration with 10 other U.S. Government agencies and departments.
- **Invests in cutting-edge scientific and technological agricultural research** to develop stronger seeds and greener fertilizers so farmers can grow more.
- **Develops agricultural markets**, expanding trade and using mobile phones to provide real-time prices, so farmers can sell what they grow at a profit.
- **Helps farmers access capital**, so they can expand their farms and buy equipment.
- **Offers extension services**, so farmers can learn the best techniques to grow and store their crops.
- **Develops sustainable agriculture strategies**, so countries can feed their populations without depleting their natural resources.
- **Reduces food insecurity among vulnerable populations** and **helps build resilience in communities facing chronic poverty and recurrent crises** such as drought via development food assistance activities under the Food for Peace program.

USAID's programming embeds value chain and market systems approaches and, per the US Government Global Food Security Strategy (see Box 1), maintains a cross-cutting focus on inclusive and sustainable agricultural-led economic growth; strengthened resilience; and nutrition. It engages a broad range of actors and stakeholders, including farmer cooperatives and producer organizations; input suppliers, agri-processors and other agribusinesses; research and extension institutions; government agencies; rural financial institutions; civil society; and universities and vocational schools.

Sections C and D of this SEG categorize this breadth of crop production programming into a more detailed set of technical interventions.

Box 1. Relationship of this Crop Production SEG to GFSS Technical Guidance

The U.S. Government Global Food Security Strategy (GFSS) for FY 2017-2021 seeks to sustainably reduce global hunger, malnutrition, and poverty by achieving three main objectives: Inclusive and sustainable agricultural-led economic growth; 2. Strengthened resilience among people and systems; and 3. A well-nourished population, especially among women and children. As noted by the strategy, "sustainable agricultural-led economic growth" is—among other characteristics—*environmentally* sustainable.

At this writing, Feed the Future (FTF) has developed 5 core and 13 supplemental technical guidance documents for designing and implementing FTF programming under the strategy, all available at https://www.agrilinks.org/post/guidance-and-tools-global-food-security-programs. This "GFSS Technical Guidance" does not focus on anticipating and addressing the wide set of potential environmental impacts resulting from crop production and its value chain.

This *Crop Production SEG* is intended to complement the GFSS Technical Guidance to support integration of environmental considerations in FTF programming and thus better achieve the environmental component of sustainable agricultural-led economic growth.

As such, there are extensive cross-references to the GFSS Technical Guidance throughout this SEG, which cannot function as stand-alone programming guidance. The environmental considerations and mitigations presented in this SEG are only effective when undertaken in the context of well-designed crop production programming; the GFSS Technical Guidance provides essential key concepts and best practices for such programming.

A.2 RISKS INHERENT IN CROP PRODUCTION

Decisions about how to address the environmental, health and social impacts in crop production must be made with understanding of the risks to profit, livelihood, and household food security that producers and other actors in the sector experience and seek to mitigate. These risks are outlined below. As noted at multiple points in this chapter, measures to mitigate environmental, health and social impacts often also reduce risks to profit, livelihood, and household food security, at least in the longer-run. However, environmental or social mitigations that may adversely affect profit, livelihood and/or household food security are unlikely to find acceptance.

Weather and Climate play a major role in determining the success of agricultural crop production. Adverse weather conditions can cause production losses, especially when they occur during critical stages of plant growth. Each individual element of weather, such as solar radiation, temperature, precipitation, humidity, and wind, can influences crops in different ways. However, simultaneous weather events can have synergistic effects.

Climate Change refers to a change in the mean and/or variability of key climate characteristics that persist for an extended period, typically decades or longer (IPCC, 2007). Climate change can significantly adversely affect crop production and is generally expected to challenge our ability to meet the growing demand for food, fiber, feed, and biofuels. However, in some locations and with respect to some aspects, changes are expected to be beneficial:

- **Crop yields and nutrition** may be influenced by the increased amount of CO_2 in the atmosphere. Crop species vary in their response to CO_2 levels. For example, plants such as wheat and soybeans, as well as many pasture grasses and forage species (i.e. alfalfa, clover, fescue) grow better when CO_2 levels are elevated. Other plants may have negligible growth responses to higher atmospheric CO_2 levels, such as corn and millet. Rising CO_2 levels have also been tied to the decrease of protein and micronutrients in crops.
- **Growing season precipitation** may increase or decrease (depending on location), as may the intensity of precipitation events. Reduction in precipitation could result in more frequent drought conditions and loss of yields, while some areas may experience increased precipitation and flooding. Crops also depend on the timing of precipitation, meaning that water stress during a critical growth phase may be detrimental to yields. Excessive rains and flooding also create problems for farmers when extreme flooding submerges crops or delays harvest, resulting in potentially devastating losses both in field and post-harvest during drying or storage.
- **Higher temperatures** could result in a longer growing season and earlier seeding times for most crops. Earlier seeding could mean increased yields in regions where there is adequate soil moisture due to greater crop growth during spring rains. Higher temperatures or changes in precipitation may influence the length of growing seasons or the types of pests found in fields, which subsequently influences crop selection.

  However, higher temperatures and longer dry spells between rain events can increase drought severity and frequency. Water-stressed areas may expand while increased demands on available water resources will affect water quality and quantity on a seasonal basis. Water storage systems may become important for farmers in areas experiencing water scarcity for the first time.
- **The effects of climate change on insects and pathogens** are likely to be mixed. However, overall, climate change will likely increase the number of outbreaks of a wider variety of insects and pathogens in most locations and see the expansion of pests into new areas.
- **Warmer air and soil temperatures** resulting from climate change may increase soil microbial activity, speeding up the natural breakdown of organic matter. If organic matter breaks down faster than the crops can use the available nutrients, soil fertility decreases. However, a longer growing season with more vegetative mass may offset the increased breakdown of organic matter.
- **The predicted increase in drought conditions, precipitation, floods, heavy winds and other extreme weather events** is expected to increase the risk of soil erosion. It may be necessary to ensure adequate ground cover at key periods throughout the growing season.

Production Risks. There are various production risks that influence the quantity and quality of products grown, including: extreme weather events such as droughts and floods; water scarcity or overabundance; difficult topography; poor soil quality (e.g., low soil fertility); diseases; pest; and lack of or malfunctioning equipment. As noted above, climate change can exacerbate (though in some cases reduce) many of these risks.

Marketing Risks. Common marketing risks include volatile agricultural markets and business cycles, fluctuating commodity prices, lack of access to markets or loss of markets, increased competition, and changing consumer preferences. Loss of market access has numerous potential causes. For example: a wholesale buyer or processor may relocate or close; transport or infrastructure may become damaged from extreme weather events; or a product could fail to meet market/buyer standards, such as food safety standards for pesticide Maximum Residue Limits (MRL) or aflatoxin[1] or other mycotoxin level standards, size/appearance standards, packaging requirements, etc.

Financial Risks include lack of cash to meet financial obligations, and limited access to credit and insurance. Sources of financial risk commonly result from production and marketing risks described above. In addition, financial risks may also be caused by increased input costs, higher interest rates, excessive borrowing, fluctuating market demand, higher cash demand for family needs, lack of adequate cash or credit reserves, and unfavorable changes in exchange rates.

Labor Resource Risk. Migration and labor availability and skill are additional factors affecting agricultural production and productivity. Lack of labor at critical times, such as at planting and harvest, can lead to higher labor costs, late planting or loss of crops in the field.

Communal and Personal Risks that can impact agricultural production include conflicts, insecurity, health issues including from use of agricultural chemicals, and worker accidents.

Legal Risks relate to fulfilling business agreements and contracts where failures tend to carry a high cost. Another major source of legal risk is when injury occurs to a person or property due to negligence. Legal risk also involves land tenure issues where uncertain land ownership can negatively impact farmer or private sector investment in the agribusiness.

Enabling Environment, Policy and Institutional Risks are those resulting from uncertainties surrounding government actions. Tax laws, regulations on chemical use, rules for waste disposal, subsidies, tariffs, and other policy changes are examples of government decisions that can have a major impact on a farm's business.

Environmental Risks faced by farmers pertain to scarcity and quality of natural resources (such as soil and water quality), erosion, loss of ecosystem services, , conflicts over access and use of natural resources, and environmental liability. These are closely related to production risks.

A.3. CONCEPTS OF ENVIRONMENTALLY SUSTAINABLE AND RESILIENT AGRICULTURE

The first of the three objectives of the U.S. Government Global Food Security Strategy (GFSS) for FY 2017-2021 is inclusive and sustainable agricultural-led economic growth. The GFSS Technical Guidance elaborates that "Within the context of this Objective, [sustainability] refers to transformative change at the systems level to create the conditions where assistance is no longer needed. In addition, agricultural-led economic growth must be sustainable from an environment and natural resources perspective as well as economically and socially sustainable" (FTF 2017).

[1] Aflatoxins are a family of toxins produced by *aspergillus* molds (fungi) that are found on agricultural crops such as maize (corn), peanuts, cottonseed, and tree nuts.

The second objective of the GFSS is "strengthened resilience among people and systems. The GFSS technical guidance elaborates that in this context resilience is "the ability of people, households, communities, systems, and countries to reduce, mitigate, adapt to, and recover from shocks and stresses in a manner that reduces chronic vulnerability and facilitates inclusive growth" (FTF 2017).

This SEG is specifically concerned with the *environmental* dimensions of both sustainability and resilience in crop production.

Environmental Sustainability in Crop Production is concerned with preventing or otherwise addressing the environmental concerns and impacts presented in Section C. In *summary*, these are as follows:

- **Water quality and quantity** concerns include runoff and leaching of nutrients and pesticides, water over-extraction, saline intrusion, drainage and flooding. Contamination of both ground and surface waters, caused by use of manure and chemical fertilizers, particularly in areas of intensive livestock or specialized crop production, can threaten water quality.
- **Air quality concerns** include emissions of ammonia and greenhouse gases (GHGs).
- **Biodiversity concerns** include genetic, species and ecosystem diversity. The expansion of agriculture has led to widespread reduction of species and habitats.
- **Landscape concerns.** The degradation of agricultural land can lead to its abandonment if farming ceases to be viable. On the other hand, conversion of land to agricultural use can lead to the loss of important landscape features and ecosystem services. For example, replacing variable vegetation and forest with agricultural fields can increase incidence of flooding and reduce aquifer recharge.
- **Soil quality concerns** including erosion, contamination, and loss of soil fertility.
- **Food safety concerns**. Agricultural practices can impact human health and animal well-being, as well as the physical environment. Food safety concerns relate to the quality and safety of the food supply, including consideration of naturally-occurring toxins and pesticides residues.

Sustainable vs. More Sustainable; Dimensions of Sustainability. Strict definitions of environmental sustainability require that a given set of crop production activities can be pursued *in perpetuity* in a given locale without adverse impacts on long-term yields, environmental quality, or ecosystem services, *and* without creating unsustainable use of resources elsewhere (e.g. in the form of fossil fuel-based fertilizer inputs). Such strict definitions of sustainability are extremely difficult to measure and achieve.

The focus in development programming thus tends to be on assuring that interventions are significantly "more sustainable" or "more environmentally sound" than "business as usual" approaches—not that they verifiably sustainable in a strict or absolute sense. This SEG and the design and other mitigation measures it outlines in Section D take this approach. And, as is clear throughout Section D, practices that are environmentally preferable in one or more respects sometimes have trade-offs in others, and selection of "more sustainable approaches" must be made with an eye towards these tradeoffs and the environmental context.

Agricultural Intensification and Sustainable Intensification. Environmental sustainability in agriculture is closely linked to the issues of agricultural intensification and sustainable intensification. Agricultural intensification—producing more food from a given area of land via increased use of one (and usually more) classes of agricultural inputs—has dramatically increased food production. Intensification is required to avoid even more extensive land conversion, which is a critical environmental impact of concern in the crop production sector (see above and Section C.1). However, the adverse environmental impacts typical of intensification—and the need to further increase food production, which would further scale these impacts—led to a call for *sustainable* intensification.

According to the Food and Agriculture Organization of the UN (FAO), "Sustainable intensification looks at whole landscapes, territories and ecosystems to optimize resource utilization and management. Farmers must produce more from the same area of land and use fewer inputs while producing greater yields" (FAO, n.d.(a)).Experts have divergent views on how sustainable intensification is operationalized, including how it differs from good agricultural practices (GAPs. see A.4.9; Petersen & Snapp, 2016). Under a strict definition of a sustainable crop production system, implementation of GAPs would generally be considered to go a significant distance in addressing environmental and social concerns --- but not of themselves to result in a sustainable crop production system.

***Environmental* resilience in agriculture** is concerned with the ability of an agricultural system to retain its productivity following an environmental change, or perturbation (after Holling, 1973). The effects of climate change are the environmental changes of most universal concern in USAID programming contexts. *Climate smart agriculture* is agriculture that is resilient to climate change. More specifically, climate smart agriculture is defined in the GFSS as an integrative approach to address the interlinked challenges of food security and climate change that explicitly aims for three objectives: (1) sustainably increasing agricultural productivity to support equitable increases in farm incomes, food security and development; (2) adapting and building resilience of agricultural and food security systems to climate change at multiple levels; and (3) reducing greenhouse gas emissions from agriculture (including crops, livestock, and fisheries), either in absolute terms or by reducing emissions intensity in the context of Low Emissions Development. This SEG suggests potential design and other adaptation measures to increase the resilience of crop production to environmental – and usually climate—change.

A.4 PRINCIPLES OF CROP PRODUCTION

Decisions about how to address the risks of environmental, health and social impacts in crop production are made within a complex economic and biological crop production system and must be taken with cognizance of the principles (i.e. key elements and "operating rules") of that system. This section briefs the key crop production principles most implicated in environmental, health and social impacts.

The section is organized according to the crop production lifecycle, beginning with crop selection, proceeding to farm and crop management, then to harvest, storage, and processing. The section concludes with two cross-cutting capstones: a subsection on farm planning, and a subsection on food safety, food safety standards, GAPs and linkage to international trade.

Figure 1. Farmers can boost crop production by adopting climate-smart practices. Photo Credit: USAID

A.4.1 SELECTION OF CROPS FOR PLANTING

Appropriate crop selection is critical to successful crop production outcomes. Factors that must be considered are: compatibility with agro-ecological zone; farming systems/methods practiced; and, in the case of crops intended for sale, market access. Each is addressed briefly below.

In general, the major factors that can affect plant growth, yield, and quality are considered by farmers for the crops and varieties they are familiar with, based on what will grow well in specific conditions. However, farmer—and especially smallholder—crop choice is often highly constrained in practice by multiple factors: farmer knowledge of other crops; availability of seed materials and other inputs, particularly for improved varieties; and access to markets; among others. The result is that farmers often end up cultivating crops and varieties that are sub-optimal for the farm's particular conditions.

Selection of Crops for Agro-Ecological Zone. Climate, landforms, water bodies, and soils combine to define land areas called "agro-ecological zones" that are conducive, in principle, to the cultivation of certain crops and varieties, but not others. The basic starting point for crop selection is compatibility with the agro-ecological zone:

- **Climate**—inclusive of daily and seasonal highs and lows; rainfall amount, intensity and seasonal distribution; relative humidity; wind conditions; light availability; nature, frequency and timing of extreme weather— is a key determinant of what crops will grow successfully and which will not. Beyond this, climate influences all components of crop production, including the timing of planting and harvesting, the area planted or harvested, and the number of crops grown within a year.

- **Landform and Water Bodies.** Landforms are the combination of topography and underlying geology, combines with climate and landcover to determine surface and groundwater availability. In general, greater water availability allows wider possibilities in crop selection.
- **Soils**—as characterized by texture, structure, organic matter content, pH, and fertility levels, *inter alia*—are likewise a key determinate of which crops will grow well; crops that are well-suited to farm soil characteristics have a far better chance of success.

Selection of Crops Considering Pests and Other Biotic Factors. Pests (including ruminant or wild animals, birds, insects, nematodes, diseases, and weeds) present in the area are a key consideration in crop selection: where a pest is known to be prevalent, susceptible crops should be excluded in favor of resistant ones. In addition, the presence or absence of organisms such as pollinators that have beneficial effects on plant growth and yield should be taken into consideration.

Selection of Crops Based on Farming Systems, such as row crop farming or mixed systems, is another key factor in crop selection. The particular crop species to be grown will depend on planting patterns and crop production practices such as monoculture, multiple cropping, and hedge row-strip cropping.

Selection of Crops Considering Markets. Where the intent is to sell the crop, selection of appropriate crops must consider marketability and profitability including product demand and supply and proximity and access to local, regional, national, and international markets. Farmers must also consider marketing capability and capacity, including availability of necessary infrastructure and logistics, ability and access to production, and marketing technology and information.

Selection of Crops Based on Household Dietary Preferences and Nutritional Value. For crops grown for home consumption, household dietary preferences have a significant effect on crop selection. Ideally, farmers will also choose crops based on nutritional value, but this often requires education.

A.4.2 USING QUALITY SEED AND PLANTING MATERIALS

Seeds and Planting Materials. Crops can be raised from seeds (e.g., grains, cowpea, beans) or from planting materials such as parts of roots, tubers, bulbs, upper branches, or stems or rootstock (e.g., cassava, banana, yams, sweet potato, potato).

The quality of seed and planting materials is critical to success in crop production. Of key concern are characteristics such as trueness to variety, germination percentage, purity, vigor, drought tolerance, resistance to pests, and appearance.

Types of Seed. Planting seed can result from open pollination (corn) or self-pollination (most vegetables, small grains, pulses, soybeans). Self-pollinating crops generally “breed true” meaning they maintain their genetic make-up and resulting plant characteristics. Open pollinated crops result from cross-breeding via wind, insects, birds, bats or other natural mechanisms and are generally more variable in their genetic make-up and plant characteristics because they are hybrids. Populations of open-pollinated crops, called Open-Pollinated Varieties (OPVs) can be quite stable.

Seeds of both self-pollinating crops and OPVs can be saved by farmers to produce many generations of crops because they remain genetically stable.

Some OPV's as well as self-pollinating crops can be considered heirlooms, meaning the seed is a traditional variety passed down from generation to generation of farmer.

Controlled hybridization of cross-pollinating crops is often done to produce specific plant hybrids; so-called "hybrid" seed should not be saved by farmers for planting because the specific plant characteristics of the hybrid will be lost over time.

Hybridization is a controlled method of pollination in which the pollen of two different species or varieties is crossed by human intervention. Hybridization can occur naturally through random crosses, but commercially available hybridized seed, often labeled as F1, is deliberately created to breed for desired traits. The first generation of a hybridized plant cross also tends to grow better and produce higher yields than the parent varieties. This phenomenon is called heterosis or "hybrid vigor."

Saved vs. Produced Seed. Grain can be saved and used as seed for sowing and planting purposes. This was the universal practice in traditional agricultural systems but leads to poor outcomes with many improved varieties: Self-pollinated crops such as soybeans and small grains (e.g., wheat, barley, rice) will generally breed true for several years, sometimes longer. Cross-pollinated crops and hybrids do not breed true, and genetic segregation will occur that results in varietal changes with each generation. Seed produced by F1 plants is genetically unstable and should not be saved for use in following years.

Produced seed, by contrast, is the result of a seed system that includes research and development, seed production, and distribution channels. Such seeds are of known varietal quality and have undergone testing. Further, produced seed often have higher levels of purity and health because effort has been made during production to remove diseased plants, weeds, and other rogue plant seeds. Produced seeds are labeled and often treated with pesticides by a manufacturer (see "treated seed," immediately below).

Classes of produced seed vary from country to country but can include nucleus, breeder, foundation, registered, and certified seed. Nucleus seed is the original propagating seed and is genetically pure. Nucleus seeds are obtained from a handful of healthy plants growing in a plot and are then grown strictly in isolation. A breeder's seed is an offspring of a nucleus seed (where a breeder is a qualified plant breeder or organization that raises plants primarily for breeding purposes). Foundation seeds are offspring of the breeder seed that can be clearly traced. They are further multiplied to give rise to certified seeds. The production of the foundation seeds must be approved by a certification agency. Foundation seed becomes "registered seed" when it has been approved and certified by a certifying agency. This is the last stage before the seed reaches a farmer. At each stage, seeds are certified and labelled. The seeds that companies sell in market are commonly called "certified seeds."

***Note**: all USAID-funded activities involving GM/GE seeds are required to comply with USAID's biosafety procedures (ADS 211).*

Figure 2. Villagers planting seedlings, Photo Credit Jeremy Holden/USAID

Treated Seed. Different seed treatments are used alone or in combination to address or prevent a number of pests, diseases and nutrient deficiencies, and to enhance plant growth. These include fungicides, insecticides, inoculants, plant growth regulators, fertilizers and fertilizer enhancers.

Pesticide treatments help to protect seeds and seedlings from disease and to fight pests that strike early in the season when seedlings are most vulnerable. Research has shown that treating seed with one or more pesticides is the most economical and efficient way to protect seed from pests during early growth stages and to improve seed quality. Prior to planting, seed is often treated with pesticides to repel or control organisms such as fungi, insects, and bacteria. Seed treatment is also known as seed "dressing". Seed treatments can be a more environmentally friendly way of using pesticides and insecticides, as the amount of product used can be very small.

It is common practice—and essential for safety reasons—to dye treated seeds to make them less attractive to birds, to make them easier to see and clean up in the case of an accidental spill, and to forewarn against consumption. The kinds of seeds that are normally treated with one or more pesticides are: corn, groundnuts, cotton, sorghum, wheat, oats, rye, barley, millet, soybeans (under some conditions), and most vegetable seed. Extra care and safety precautions must be taken when applying pesticides and in handling seed after it has been treated, including ensuring that treated seed is properly labeled.

Note that the insecticides most often used in seed treatments are neonicotinoids, which present concerns regarding aquatic organisms and bees; see C.4.1.

Genetically Modified Seed. Seed genomes have long been modified through traditional plant breeding techniques. However, commercial use of genetically modified (GM) or genetically engineered (GE) seeds produced via modern genetic science date only to 1994. GM/GE seeds are generally *transgenic*, meaning they have been modified with elements of the DNA of a species different than the one being altered. (Emergent gene editing approaches may result in GM/GE seeds that are not transgenic [cf Rotman 2017].) The purpose of doing so is to introduce a desirable trait to the target species. Acceptance of GM crops/seeds varies widely, and is subject to a range of national regulations, from approval procedures to outright bans.

Microbial inoculants may help improve the nitrogen fixation in legumes, and, in some cases, can stimulate plant growth or promote soil biodiversity. Inoculants may be necessary for legumes such as soybeans, cowpeas and groundnuts (peanuts). These crops fix their own nitrogen in the soil via a symbiotic relationship with specific soil bacteria, generally of the genus *Rhizobium*. If the appropriate Rhizobia bacteria are not native to a particular soil, and especially if planting the legume crop for the first time in an area, seed can be treated, or inoculated, with the specific bacterium for that crop.

Formal, Informal, and Integrated Seed Systems. The formal seed system can be characterized by a formal set of actors and steps. It usually starts with plant breeding that promotes materials for formal variety release and maintenance. Regulations exist in this system to maintain variety, identity, and purity, as well as to guarantee physical, physiological, and sanitary quality. Seed marketing takes place through officially recognized seed outlets, such as national agricultural research systems and government subsidized or funded development seed programs. Formal systems make a standards-based distinction between "seed" (which is planted) and "grain" (which is eaten). Formal systems are especially important when seed is used to grow crops for commercial purposes (i.e., export or further food processing) when the uniformity and high quality of the product must be guaranteed.

Informal seed system activities tend to be integrated and locally organized to embrace the most common ways farmers produce, disseminate, and procure seed (e.g. directly from their own harvest, through barter among friends, neighbors and relatives, and through local grain markets or traders) (David & Oliver, 2002). Integrated seed systems imply coordinated actions between formal and informal systems (Sperling, Boettiger & Barker, 2013).

Seed Security. Farms are seed secure when they have access to seed and planting material of adequate quantity, acceptable quality and in time for planting. Despite the obvious connection, seed security is not the same as food security and needs to be assessed separately (Seed Aid for Seed Security, 2014).

A.4.3 FIELD PREPARATION AND CROP PLANTING: PURPOSE AND PROBLEMS OF TILLAGE

Tilling, or turning the soil, by human labor or via animal or mechanical traction, is the most common way to prepare the field for planting. Tilling creates a seedbed where seeds can germinate easily, but also helps to loosen and aerate the soil, incorporate fertilizer, and/or control weeds.

However, tilling presents a number of environmental and long-term farm productivity concerns:

- Tilling the soil at the same depth season after season can create a hardpan (impervious layer) that restricts plant root growth in certain soils.

- Although tilling increases soil pores in the short-term, once the soil settles, soil pores can collapse. This results in soil crusting and surface sealing which can impede rainfall infiltration and result in erosion, even on moderate slopes. Reduced infiltration of rainwater into soils reduces water availability to plants, increases surface runoff, and reduces groundwater recharge.
- Tillage reduces the amount of organic matter in the soil, thereby reducing soil fertility and crop yields. The continuous soil preparation by hoe or plow leaves the soil exposed to rain, wind, and sun. Soil organisms are destroyed by exposure to solar radiation and rapid drying of the soil. Soil inversion (plowing) increases the rate of decomposition of organic matter in the soil through oxidation and leads to soil compaction and increased soil water loss through evaporation.
- Tilling increases erosion, decreasing the depth of topsoil on the farm. Beyond the farm, this pollutes surface waters and increases sedimentation.
- Tillage can bury weed seeds in the soil causing them to persist longer than they would if they remained on the soil surface, thus increasing weeds and their variability.
- Tillage releases CO_2 into the atmosphere, contributing to climate change.

Conservation agriculture strategies[2] can reduce the need for tillage by maintaining a cover of vegetation or mulch on the surface, raising the organic matter content of the soil and improving soil fertility while reducing the amount of CO_2 produced. Conservation agriculture also protects the soil from erosion, which helps protect surface waters from silt.

However, in production agriculture, tillage is used primarily as a weed control tool, whereas in conservation agriculture, herbicides are mainly used for weed control. Herbicide use tends to increase with less tillage (FAO, 2007).

A.4.4 PLANT NUTRITION: SOIL FERTILITY, INTEGRATED SOIL FERTILITY MANAGEMENT, AND BIOSTIMULANTS.

Good plant nutrition is necessary for successful crop production and soil properties are a primary determinant of good plant nutrition. Loss of soil fertility and productivity is a key challenge in crop production, and occurs through multiple routes, including: erosion and leaching[3]; nutrient mining (removal of more nutrients through crop production than are added back to the soil); physical degradation of soil (poor structure, compaction, crusting, waterlogging, etc.); a decrease in organic matter content and soil bioactivity; soil acidification, salinization; alkalization; soil pollution; and, generally, inefficient soil management.

In general, rather than remediating the land afterwards, it is easier to prevent erosion and other forms of soil productivity loss by managing and sustaining soil fertility as an integral part of a productive farming system. This is called integrated soil fertility management (ISFM), defined as "a set of agricultural

[2] Conservation Agriculture is defined by FAO as a farming system characterized by the application of three principles: (1) Minimum mechanical soil disturbance (i.e. no tillage) through direct seed and/or fertilizer placement; (2) Permanent soil organic soil cover (at least 30 percent) with crop residues and/or cover crops; and (3) Species diversification through varied crop sequences and associations involving at least three different crops" (FAO 2017b).

practices adapted to local conditions to maximize the efficiency of nutrient and water use and improve agricultural productivity" (IFDC). These practices may include:

- Use of soil amendments including: farmyard manures and green manures; natural and mineral fertilizers; crop residues and farm wastes; and others (e.g. lime);
- Agroforestry and tillage practices;
- Use of cover crops;
- Intercropping and crop rotations, including legumes;
- Fallows;
- Irrigation and drainage; and
- A variety of other agronomic, and vegetative and structural measures designed to conserve both water and soil.

Further information on these measures is provided in Section D.

Beyond measures under the umbrella of ISFM, in a given farming context there may be a role for biostimulants in supporting plant nutrition. Definitions of biostimulants vary, but the following is representative: "any substance or microorganism applied to plants with the aim to enhance nutrition efficiency, abiotic stress tolerance and/or crop quality traits" where the effect does *not* arise from the nutrient content of the substance (du Jardin, 2015). Biostimulants include humic and fluvic acids, amino acids, seaweed extracts, chitosan and other biopolymers, and beneficial fungi and bacteria, among others (ibid.) Regardless, the quantities used are very small compared to traditional soil amendments.

Biofertilizers are a sub-class of biostimulants. Again, definitions vary, but the following is representative: "any bacterial or fungal inoculant applied to plants with the aim to increase the availability of nutrients and their utilization by plants, regardless of the nutrient content of the inoculant itself" (ibid). Generally, they intend to accelerate certain microbial processes in the soil which increase the availability of nutrients in a form easily assimilated by plants (Paul & Dubey, 2014).

Biostimulants are a rapidly developing market sector and area of agricultural research and practice, with varying levels of effectiveness depending on the product and context. Regulatory definitions and treatment of biostimulants and biofertilizers are currently only emergent.

A.4.5 MANAGEMENT OF SOIL MOISTURE AND USE OF IRRIGATION

Soil moisture and its availability to support plant growth is a primary factor in farm productivity. Too little moisture can result in yield loss and plant death. Too much causes root disease, loss of soil nutrients, plant death and wasted water. Irrigation in the correct amount and frequency promotes optimal soil infiltration and plant growth. For irrigation to be effective and land productivity to be maintained (even in the medium term), local conditions must be considered, such as soil structure, soil texture (proportion of sand, silt, and clay), vegetation, size of the area to be irrigated, water availability, and water pressure (Pitts, 2016). Irrigation is addressed in Annex 1.

A.4.6 CROP PROTECTION

In the field, crops are subjected to a range of biotic and abiotic stresses. Abiotic stress refers to damage that is caused by non-biological agents such as drought, floods or wind storms. Biotic stress is defined as a stress in plants due to damage instigated by other living organisms (i.e. pests). Crop protection is essential to successful crop production and includes biotic and abiotic stress control. Key concepts in crop protection are outlined below:

Pests. In the context of crop production, the term "pests" refers to harmful organisms that attack, interfere with, or feed on plants, rendering them partially or fully damaged and unsuitable for harvest. Plants can be damaged by fungi, bacteria, viruses, insects, nematodes, herbivores (including birds and other animals), and competing plants, such as weeds.

Pesticides are "any substance or mixture of substances intended for preventing, destroying, repelling, or mitigating any pest."[4] A commercial pesticide product typically consists of a specific concentration of one or more Active Ingredients (AIs) that kill, repel, or "regulate" the pest in a specific formulation (aerosol, bait, dust, etc.) with a specific "recipe" of inert ingredients. Inert ingredients may include: surfactants to make the pesticide stick to the pest or plant; synergists that enhance the pesticide's action; carriers like water, oil, or a solvent; fragrances and dyes, etc. The name is misleading, as inert ingredients may themselves be toxic.

However, commercial pesticides are not limited to chemical products:

- **Biopesticides**, as defined by the US EPA, are "certain types of pesticides derived from such natural materials as animals, plants, bacteria, and certain minerals". Categories of biopesticides include: 1) microbial pesticides, in which a microorganism (e.g., a bacterium, fungus, virus or protozoan) is the AI; and 2) biochemical pesticides, which are naturally occurring substances that control pests by non-toxic mechanisms, such as sex pheromones that interfere with mating and scented plant extracts that attract insect pests to traps.
- **Plant-incorporated Protectants.** Plant-incorporated protectants (PIPs) are "plants that have had genes inserted causing the plants to produce a pesticide inside its own tissues" (e.g., Bt insecticidal protein in cotton). When plants are genetically modified to produce pesticides in this manner, they are regulated as pesticides by the US EPA. The toxin and its genetic material, but not the plant itself, are regulated by the EPA (NPIC, 2017).
- **Biostimulants** (see A.4.4) containing biochemical, microbial, or PIP active ingredients may be registered by US EPA as pesticides (Jones, 2016).

Globally, the commercial pesticide market is estimated to be worth approximately $70bn annually with approximately 1,200 AIs in tens of thousands of products. Pesticides present a number of health and environmental risks described in Section C.

Integrated Pest Management (IPM). There are a number of definitions of IPM in use; the following is widely used and representative: "ecologically-based pest management that promotes the health of crops and animals, and makes full use of natural and cultural control processes and methods, including

[4] This definition is written into the US Federal Insecticide, Fungicide and Rodenticide Act [FIFRA]. Varieties of pesticides include: insecticides, acaricides, fungicides, rodenticides, nematicides, ovicides, molluscicides, microbicides, virucides, antifoulants, attractants, repellants, pheromones, herbicides, algaecides, insect growth regulators, plant growth regulators, plant incorporated protectants, nitrogen stabilizers, desiccants and defoliants.

host plant resistance and biological control [and that] uses chemical pesticides only where and when the above measures fail to keep pests below damaging levels […] all interventions are need-based and applied in ways that minimize undesirable side effects" (CGIAR Policy Statement on IPM).

The concept of IPM was developed as a response to the health and environmental impacts observed from high reliance on chemical pesticides. Biological control—the use of parasites, pathogens and predators to reduce the population of pests—is one of many IPM techniques. (See D.4.3 for further discussion of IPM.)

***Note**: USAID's Pesticide Procedures at 22 CFR §216.3(b)(1)(i)(c) require that authorization for USAID assistance for the procurement or use of any pesticide must consider the extent to which the proposed use is part of an IPM program. See D.4.3*

Figure 3. Locusts swarms can include tens of millions of insects. Wherever they land, crop or pasture loss can be 100 percent within hours. Photo Credit: USAID/OFDA

Abiotic Stressors. Plants can also be damaged by noninfectious factors, causing problems that can collectively be termed "abiotic diseases" or "abiotic disorders." Per Kennelly et al. (2012), "unfavorable soil properties, fertility imbalances, excess salts, chemical toxicity, lack or shortage of nutrients, water shortages, moisture extremes, temperature extremes, physical injuries, and other problems are examples of abiotic disorders that can reduce plant health and even kill plants. Furthermore, many of these abiotic disorders can predispose plants to diseases caused by infectious microbes." Understanding abiotic disorders is critical for managing overall plant health.

A.4.7 HARVESTING AND POST-HARVEST HANDLING, STORAGE, TRANSPORT AND PROCESSING

Beyond growing the crop successfully to harvest, successful crop production requires appropriate harvest, post-harvest handling, storage, and processing practices to best ensure that the crop is healthy to consume, storage losses are minimal—and in the case of cash crops, safety and quality standards are met. (See Food Safety and Quality in A.4.9.) Attaining quality standards is critical to the price producers receive, and often to the ability to market the crop at all.

Elements of appropriate harvest, handling, and storage related specifically to safety and quality include, but are not limited to:

- Observation of pre-harvest intervals for pesticide application;
- Safe transport of commodities;
- Pest control in storage and processing facilities, often including fumigation;
- Cleanliness of equipment, worker hygiene, quality of processing water; and
- Process controls including, for example, assuring correct moisture content and temperatures for storage.

Beyond the food safety/public health concerns that must be addressed, the harvest, post-harvest, storage, transport, and processing stages of the crop production cycle present environmental and occupational health and safety concerns, including but not limited to:

- Environmental and occupational health risks from use of pesticides and other chemicals, including fumigants;
- Potential for occupational injury from equipment; and
- Environmental impacts arising from the abstraction of processing water and its discharge, often with heavy biological and chemical oxygen demand.

These issues are elaborated in section C.7. Good Agricultural Practice (GAP)/Good Handling Practice (GHP) schemes (see section A.4.9) address harvest, handling, storage, and processing of crops for food safety/quality endpoints---and increasingly environmental and occupational health and safety concerns as well. Regulatory requirements may apply to harvest and handling, and very often to storage and processing.

Note: *USAID activities that support phosphine fumigation of agricultural commodities must comply with the requirements of USAID's Programmatic Environmental Assessment (PEA) for Phosphine Fumigation of Stored Agricultural Commodity.*

A.4.8 FARM (PRODUCTION FACTOR) PLANNING FOR CROP PRODUCTION

In crop production, the efficient allocation and utilization of resources, or production factors—land, labor, water, agricultural inputs (fertilizer, planting materials, seeds, pesticides), equipment, credit, information, farming technologies and innovation, institutional support, among others—is necessary to maximize income and minimize costs on a sustainable basis.

This can usually only be achieved through a deliberative process of *farm planning* focused on all farm assets (physical and nonphysical). This requires that the farmer/planner be knowledgeable about assessing land capability and farm potential. A holistic approach to farm planning is implicit in the concept of sustainable intensification presented in section A.3.

Planning itself, however, does not assure increasing, **sustainable** farm productivity. First, unforeseen risks (see A.2, above) can have adverse effects. Second, the planning time horizon must be compatible with a sustainable productivity objective. For example, exploitation of land and water resources to maximize short-term farm income can lead to soil and water degradation and depletion of groundwater, imposing significant opportunity costs in the long term (Haque, 2006).

All farmers do some form of daily planning on their farms. This is distinct from the holistic planning described here. Smallholders are typically highly resource-constrained—particularly with respect to technology, credit, and agricultural inputs—and thus have a strong need to use production factors efficiently. Unfortunately, smallholders are also often least-equipped in terms of knowledge, information and options to engage in effective farm planning, and often least able to trade short-term income for long-term benefits.

A.4.9 FOOD SAFETY, FOOD SAFETY STANDARDS, GOOD AGRICULTURAL PRACTICES AND LINKAGE TO INTERNATIONAL TRADE

Food Safety and Quality. Food safety and quality is critical to public health. Safety and quality can be compromised by multiple means including, but not limited to:

- Pathogens introduced by unsanitary production, harvest, handling and/or storage practices. Examples include contaminated irrigation water, use of green manure, lack of appropriate sanitary facilities for farm workers, livestock in fields, and rodents in stored commodities;
- Chemical contamination resulting. from poor pesticide choices and use practices, (e.g., *aspergillus* molds causing aflatoxin contamination, heavy metals in soil, etc.); and
- Physical contaminants such as stones and twigs.

Government Food Safety and Quality Standards. By statute and regulation, governments have long established food safety/quality standards and enforcement mechanisms. Generically, these standards may take the form of:

- Specific quality measures that must be met (e.g. freedom from pests and pathogens; maximum residue limits for pesticides);
- Process (practice) requirements that apply to production, processing, storage and transport (e.g. temperature and time specifications for pasteurization processes); and
- Provenance requirements (e.g. that goods come from a disease-free area). For crops, this is rarely a restriction based on a concern over whether the crop is safe to eat, but rather arises out of a concern over introducing a plant pest into a new area.

In setting food quality/safety standards, many developing country governments rely heavily on the Codex Alimentarius . The Codex Alimentarius is a collection of food safety standards, guidelines and codes of practice adopted by the Codex Alimentarius Commission), which is the governing body of the Joint FAO/World Health Organization (WHO) Food Standards Programme (see www.fao.org/fao-who-codexalimentarius/en/).

The actual safety of food available in a given market depends on the standards that are in place and their enforcement—but as much or more on the prevailing practices, infrastructure and capacities in place across the agricultural value chain.

(In the US, the 2011 Food Safety Modernization Act significantly updates US national regulation of food safety, providing the US Food and Drug Administration with significant new regulatory authorities, including mandatory recall authority. Widely reported incidents of food-borne illness were a major impetus to passage of the law.)

Figure 4. Purdue's hermetic grain storage technology is a triple-layer bag composed of two inner liners and an outer sack of woven polypropylene, which can almost eliminate grain storage losses from insects and can greatly reduce losses from mold and mildew. Photo credit: Beksoubo Damienne/USAID

Good Agricultural Practices (GAPs). Generically, GAPs are specific methods, which when applied to agriculture, should produce food that is safe and wholesome for consumers. Their scope includes (but is not limited to) water quality, manure and compost use, worker health and hygiene, and prevention of contamination from wildlife, domestic animals, and livestock. Increasingly GAPs also address environmental stewardship, fair labor practices, and reducing carbon footprint (FAO, 2016).

Implicit in the concept of GAPs is not simply that they are good practices, but that they are good practices whose attainment is certified.

There is not a single global, universal set of GAPs, but rather multiple schemes, some of which compete within a given market. While there are significant commonalities across GAPs for different crops, there is necessarily significant crop-specificity owing to differences in cultivation, harvest and processing for different crops.

GAPs are generally distinct from government food quality and safety standards, but they are increasingly becoming linked to these standards, often in complex ways. For example, regulatory agencies may be a stakeholder in efforts by the private sector to develop GAPs so that they are harmonized with regulatory requirements. Regulatory agencies may also support GAP audit programs as a form of technical assistance to better help producers and processors meet regulatory standards, or to access export markets.

Note: *the above discussion regarding GAPs also applies to Good Handling Practices (GHPs), which are focused on post-harvest handling and address processing water quality, sanitation of the packing house, pest control programs, and sanitation of containers.*

Private Sector and Civil-Society Standards. Over the past two decades, private-sector GAP standards focused on safety and civil society standards that address environmental and/or social characteristics of crop production have grown significantly in market importance. (This focus is relative. As noted above, GAPs increasingly address environmental stewardship and labor practices. Civil society standards, while focused on the environmental or social characteristics of production, do not ignore food safety.) A small sample is as follows[5]:

- **Private sector**. Global G.A.P. (www.globalgap.org) which develops and administers the eponymous family of standards, describes itself as a "global organization with a crucial objective: safe, sustainable agriculture worldwide. We set voluntary standards for the certification of agricultural products around the globe." Global G.A.P. is currently the private sector GAP standard under which the largest value of certified goods is sold, though there are others (e.g., British Retail Consortium). It is governed by a board evenly balanced between producer and retailer representatives.
- **Civil Society**. Fairtrade International (www.fairtrade.net), which develops and administers the Fairtrade family of standards, describes itself as a "global organization working to secure a better deal for farmers and workers." Fairtrade standards: focused on social conditions of production and remuneration of producers.
- **Civil Society**. Rainforest Alliance (www.rainforest-alliance.org), which develops and administers the "Rainforest Alliance Sustainable Agriculture Standard" describes the standard as being "built on these important principles of sustainable farming: biodiversity conservation, improved livelihoods and human well-being, natural resource conservation, [and] effective planning and farm management systems."

[5] *Note: Descriptive quotations are taken from home or "about" pages on the website of each organization, accessed Nov. 2018. Inclusion of an organization/standard in this list does not imply USAID endorsement.*

From the producer perspective, certification to private sector/civil society standards is voluntary and can be desirable, as in principle they permit premium pricing/access to higher-value market segments. In contrast, certification under a private sector GAP standard is increasingly required simply to sell into (access) developed-country markets---not as a government requirement, but because purchasers demand it, reflecting consumers' demand for safe and more sustainably produced food.

In contrast to governmental food safety standards, for which agencies of government generally function as enforcement agents, attainment of/compliance with private-sector and civil society standards is *certified*—usually for a fee—by the organization that "owns" the standard, or by a third party accredited by the standards organization.

International Agricultural Trade, Government and Private-Sector Standards. All developing countries engage in agricultural trade at least to some extent to meet food security needs, to satisfy consumer preferences, and/or to export. In the case of some, the export performance of the crop production sector is critical to national economic performance. With respect to trade in crops and crop products, export is the primary concern of this document, as crop export is a frequent focus of USAID crop production activities, whereas import is not.

This said, import of *seed and planting materials* is a frequently supported crop production activity; such imports are subject to host government restrictions intended to assure that pests do not accompany seeds and planting materials (phytosanitary restrictions, and that new crops and varieties are introduced only with appropriate review and consideration.

To export a crop into a given market, the governmental quality and safety standards of the export market must be met. However, as noted above, certification to private sector GAP standards is increasingly required to sell into developed-country markets, and GAP certification generally helps achieve governmental quality and safety standards that apply in these markets. As such, private sector GAP standards provide opportunities for developing-country producers to access developing-country markets in a way that offers built-in mitigations regarding a number of environmental and social concerns. However, they are also challenging, as requirements and certification costs are often beyond the unassisted capabilities of developing-area producers and agribusinesses.

Beyond this, many other challenges exist to successful export of crops produced by developing-area smallholders, including tariffs; lack of economies of scale; and multiple deficiencies in the enabling environment (see A.6, below) such as poor market information; and expensive, unreliable and/or inadequate in-country infrastructure for storage, transportation and shipment. (See A.6 Enabling Environment, below; also Greenville, 2015; Gibson et al., 2001). Addressing infrastructure challenges in particular entails environmental risks, discussed in Section C.

A.5 AGRICULTURAL VALUE CHAINS

A value chain is the set of transactions that takes place between all actors (firms and individuals) involved in the chain of production that transforms raw materials/inputs into the good or service purchased by the final consumer. Each step in this chain of production is a *segment*: segments in almost all crop production value chains include: inputs suppliers, producers, transportation companies, processors, wholesalers and retailers.

Value chain analysis determines the opportunities (leverage points) and constraints to adding value in each value chain segment. ("Value added" is the difference between (1) what an actor makes in total sales to the next segment of the chain, and (2) what that actor spent on raw materials, services and components needed.) For example, where are inputs not sufficient or unavailable? Which segments are under-developed? Where are transactions not physically possible because linking infrastructure (roads) are not present? Where are rates of profit or return on capital much lower than those in sectors that compete for this capital?

In this way, value chain analysis points to interventions needed to strengthen the *enabling environment*; discussed immediately below.

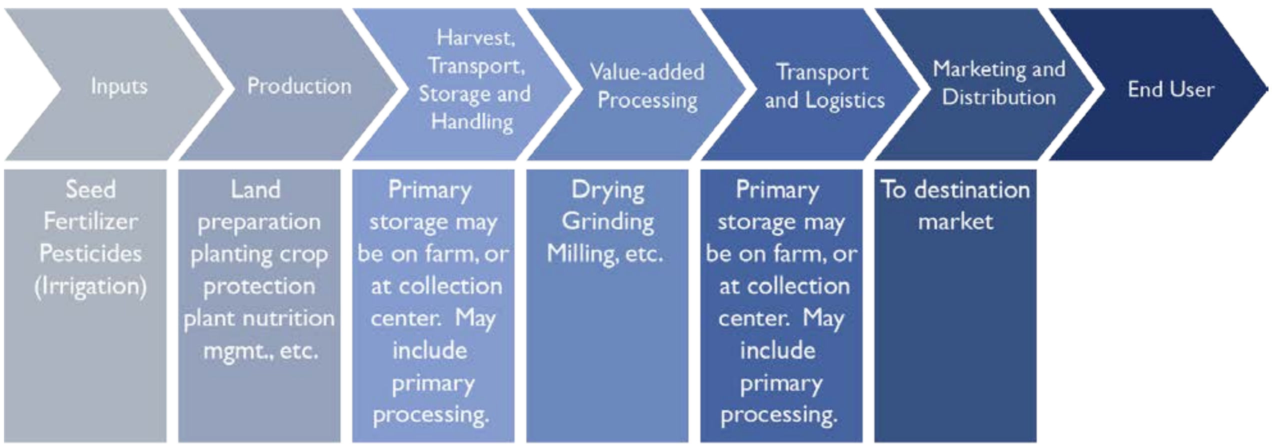

Figure 5. Agriculture Value Chain

A.6 ENABLING ENVIRONMENT

For crop production to best support food security and/or economic development, the enabling environment is critical: this is the complex of market and trade policies, physical infrastructure (such as roads and irrigation), financial infrastructure, social infrastructure (such as education, research and innovation), and institutions and regulations (Agriculture for Impact, n.d. (a)) that, for example determine whether or not:

- High-quality planting materials for crop varieties appropriate to local conditions and other critical agricultural inputs are widely available.
- Actors at any given segment of the value chain are incentivized to invest in their operations.
- Crops can be transported to market centers at economic time and costs.
- Crops marketed to consumers are healthful.
- Producers have access to credit and to de-risking mechanisms.

While the importance of market access roads and water management infrastructure is clear, the policy, legal, information, institutional, educational, extension and research aspects of the enabling environment are likewise important:

Agricultural Policy relates to domestic agriculture and imports of foreign agricultural products. Governments usually implement agricultural policies with the goal of achieving a specific outcome in the domestic agricultural product markets. Important agricultural policy objectives for governments of developing countries have typically included increased production of food and cash crops and higher rural incomes.

Note*: For concepts and best practices for agricultural policy programming generally, see Global Food Security Strategy Technical Guidance: Policy Programming.*

Agricultural Laws and Regulations implement agricultural policy—or other functions and mandates of government (such as consumer health and occupational safety) as they apply to the agricultural sector. As such, their scope is typically significant, including agricultural infrastructure, inputs, finance, labor, marketing, insurance, land tenure and tenancy, product safety and quality (see A.4.8), water rights, and pricing.

The history of agriculture policy and its enabling laws and regulations has many examples of unintended effects. For example, price controls intended to benefit consumers can result in decreased production as producers are disincentivized; or water rights accorded to assure agricultural production result in highly inefficient water use. This history dictates the environmental and social effects of prospective policy, laws and regulations be closely considered; see Section C.5.

Agricultural Market Information. Timely information on market standards, input and product markets prices, weather, and other factors helps farmers make informed decisions about where to buy inputs, what crops to plant and where to sell their products—thus increasing competitiveness, reducing information asymmetries and improving market efficiency. Similarly, market information can help traders identify areas where produce is available for purchase, markets with good arbitrage possibilities, and sometimes, farmers and other traders with whom they can trade (FAO, 2017). However, learning how to interpret and act on market information often requires external assistance; see agricultural extension, below.

Agricultural Institutions. There are numerous formal international and national institutions and organizations in each country directly and indirectly involved in crop production, protection, processing, research and marketing that can drive or hinder the enabling environment. The formal institutions such as government ministries, departments and agencies; agricultural research institutions; and agricultural extension organizations have legal recognition. Formal institutions provide the framework within which farmers and agribusinesses operate.

There is an important distinction between formal institutions and informal institutions which may not be formally registered and which operate based on community principles, traditions and customs. Ideally, strong institutional frameworks include a balance between formal and informal social groups and organizations that work together on such issues as the enforcement of property rights, the stimulation of agricultural investment, and providing limitations on the activities of powerful groups. Local groups and organizations are therefore integral to building social capital within otherwise excluded or impoverished communities. Local, informal groups and organizations have a central role to play in the sustainable and equitable management of natural resources, including agricultural land, forests and water. Informal institutions such as customary land tenure systems, social customs, norms, and networks are crucial for regulating how natural resources are accessed and managed (Agriculture for Impact, n.d. (b).

Formal Agricultural Education. Agricultural education is typically a significant focus of developing-country universities, colleges and trade schools, which play an important role in capacity development and promoting acceptance, adoption, and use of innovative crop production technologies.

Agricultural Extension and Training. Agricultural extension services are known to be critical to successful crop production outcomes. They provide farmers with guidance on new and appropriate technologies and best management practices for various crops, as well as how to interpret market information. They also often connect farmers with other support services such as access to finance and inputs. Agricultural extension can be provided by public and private sector actors, as well as by civil society. These actors often have somewhat different orientations (e.g. promotion of national policy goals, profit, and beneficiary welfare, respectively), but seek to achieve their objectives by sharing knowledge to influence the decisions and practices of large numbers of rural farm households. (FAO, Farm Management Extension Guides, 2013).

Agricultural education and extension provide high-leverage channels to address appropriate environmental and occupational safety and health practices. Conversely, failing to address these practices in education and training will almost certainly result in the prevalence of poor practices.

Crop Production Research can address a multitude of issues including plant breeding, genetics, plant physiology, production ecology, soil and water science, pest control, and other issues. The past two decades have seen a dramatic increase in global cultivation of GM/GE crops—organisms into which scientists have intentionally introduced genetic material that confers new traits. In an agricultural development context, this includes efforts to develop and disseminate smallholder-appropriate GM/GE crops with traits that address food security priorities, such as improved nutritional content, climate resilience, reduced environmental impact, or resistance to pests and diseases. The private sector is playing an important role in developing technologies to raise productivity in agriculture. National policies can have a significant effect on the willingness of the private sector to invest in agricultural research and development.

Figure 6. Zijadin Kelmendi, a first-time chili pepper grower, sold 1,000 kilograms of the crop to a local collection center after the second day of harvest, under a program that combines market development and extension to enhance the sustainability and competitiveness of targeted Kosovo agribusinesses in domestic and export markets. Photo Credit: USAID

B: QUICK REFERENCE GUIDE—SUMMARY OF CROP PRODUCTION IMPACTS AND MITIGATION MEASURES

The Quick Reference table below *summarizes* potential environmental impacts and mitigation measures for each type of intervention (action) in support of crop production addressed in Section C (Impacts) and Section D (Mitigation) of the main text.

Note: *The table does not capture all crop production impacts or mitigation measures, or key discussion regarding these impacts and mitigations. For full discussion and use in mitigation and monitoring plans, see Sections C and D. Links to discussion in the main text are provided throughout the table.*

TABLE 1. SUMMARY OF CROP PRODUCTION ACTIONS, ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES

CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
Crop Production: Environment, General	• Degradation and fragmentation of landscapes • Isolation of animal populations • Disruption of ecosystem services • Deforestation • Desertification • Grassland degradation • Soil erosion • Reduction in soil fertility • Release of greenhouse gases • Loss of biodiversity • Introduction of non-native species • Siltation of water bodies • Reduction in surface and groundwater quality • Pollution of air, water, sediment and soil • Climate change and GHG emissions. (FULL DISCUSSION OF GENERAL CROP PRODUCTION IMPACTS AT C.1.1) (FULL DISCUSSION OF IMPACTS ASSOCIATED WITH SPECIFIC LANDSCAPES AT C.1.2) (FULL DISCUSSION OF IMPACTS ASSOCIATED WITH SPECIFIC CROPS	Category: Preserving Land and Landscapes • Minimize agricultural land expansion by intensifying production • Promote alternative livelihoods • Maintain appropriate riparian buffers • Use land in conformity with its capability • Implement erosion control practices • Improve land use planning • Address insecure land tenure • Support shifting cultivation only in sustainably managed forests/landscapes • Support land clearing only with detailed assessment and thorough mitigation Category: Preserving Biodiversity • Conserve land to preserve biodiversity • Promote alternatives to monocropping • Prevent introduction of invasive species • Replanting and introducing local species Category: Controlling Pollution • Implement erosion/runoff control measures and riparian buffers

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
	AT C.1.3)	• Control leaching • Managing pollution from irrigation and drainage • Control volatilization and drifts • Promote alternatives to burning crop residue and farm waste • Reduce GHG emissions intensity (FULL DISCUSSION AT D.1.1 – D.1.3) Category: Managing Soil Fertility and Soil Conservation • Characterize soils and practice integrated soil fertility management (ISFM) • Prevent and manage soil waterlogging • Prevent and reduce soil compaction • Amend soil as indicated based on properties • Use fertilizers safely • Undertake manuring and composting • Mulch when appropriate • Identify and manage soil salinity, acidity, alkalinity, specific ion toxicity, and sodicity (FULL DISCUSSION AT D.1.4) Category: Water Management and Water Conservation • Conserve soil moisture • Harvest rainwater to reduce draw on surface and groundwater • Construct and maintain diversions (requires engineering oversight) (FULL DISCUSSION AT D.1.5) Cross-Cutting Category: Crop Residue

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
		Management and Tillage • Use crop residue as soil cover • Practice conservation tillage • Undertake deep tillage/deep plowing/subsoiling/ripping • Plow on the contour • Implement raised beds • Carry out land leveling (requires engineering oversight) (FULL DISCUSSION AT D.1.7.1) Cross-Cutting Category: Planting Design and Cropping • Manage seeding/planting date • Seed/planting material selection • Rotate crops • Consider Polycropping/polyculture • Optimize planting density and inter-row spacing • Grow cover crops • Use fallow periods • Establish and maintain critical area planting areas • Establish and maintain field borders (FULL DISCUSSION AT D.1.7.2 & 3) Category: Energy Use • Use efficient, clean-burning equipment. • Use synthetic fertilizers only as required • Use renewable energy sources • Sequester carbon on agricultural land (FULL DISCUSSION AT D.4.6)

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
Crop Production: Social, General	Women and Vulnerable Groups • Take children—and potentially, particularly girls—out of school to provide farm labor. • Health impacts from operating machinery, spraying chemicals, and pesticide application. (FULL DISCUSSION AT C.9.1) Cultural Sites • Destroy or disturb sites of historic or religious/sacred significance. • Stimulate land conversion or site repurposing away from intervention sites. (FULL DISCUSSION AT C.9.2) Land Tenure • Land conversion to commercial farming • Dispossession of smallholders' land • Lack of acceptance of sustainable land productivity (FULL DISCUSSION AT C.9.3) Loss of Ecosystem Services and Appropriation of Natural Resources • Land conversion may result in increased abstraction of water for agriculture • land-use conflicts. (FULL DISCUSSION AT C.9.4) (FULL DISCUSSION OF SOCIAL IMPACTS OF CROP PRODUCTION AT	Health and Safety • Address Occupational and Community Health and Safety in Pre-implementation ESIA process (e.g., the USAID IEE or EA). Women and Vulnerable Groups • Undertake pre-implementation gender and related social analyses • Predicate Assistance on Keeping Children in School and Monitor. (FULL DISCUSSION AT D.9.1) Cultural Sites • Identify cultural sites in the design stage • Design for avoidance and monitor indirect impacts (FULL DISCUSSION AT D.9.2) Land Tenure • Understand local land tenure and land uses • Incorporate a project component to strengthen land tenure (FULL DISCUSSION AT D.9.3) Loss of Ecosystem Services and Appropriation of Natural Resources • Use an ecosystem service frame in ESIA process • Design and mitigate to prevent loss of ecosystem services (also see mitigation measures in D.1). • Address land tenure, gender and vulnerable groups issues (see mitigations above) • Consider a community-based natural

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
	C.9)	resource management (CBNRM) approach (FULL DISCUSSION AT D.9.4)
Supporting Agricultural Policy	• Land conversion • Increased use of water or other inputs • Displacement of food security crops. (FULL DISCUSSION AT C.2.1)	• Building awareness among policy makers about the importance of integrating environmental, social and ecosystem services considerations into policy decisions • Providing technical training to legislative or ministry staff regarding the necessary analytical tools to support such integration • Collaborating with civil society actors to strengthen ability of the civil society to influence policy • Efforts to bridge university research and expert knowledge into the policy making process • Promoting media involvement in communicating policies and their potential social and environmental impacts. • *See Global Food Security Strategy Technical Guidance; Policy Programming* (FULL DISCUSSION AT D.2.1)
Support for Trade and Investment	• In countries where capacity to enforce environmental management standards is low, more input-intensive production can lead to adverse environmental impacts. (FULL DISCUSSION AT C.2.2)	• *See GFSS Global Food Security Strategy Agricultural Trade Technical Guidance* (FULL DISCUSSION AT D.2.2)

TABLE 1. SUMMARY OF CROP PRODUCTION ACTIONS, ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES		
CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
Support for Extension Services	• If focused on intensification or adoption of cash crops, can involve increased use of fertilizers, pesticides, or mechanization, or stimulating land conversion and displacement of subsistence-farmer tenants. (FULL DISCUSSION AT C.2.3)	• Promote crops/varieties and approaches that are proven in practice appropriate to the agro-ecological zone and farmer capabilities • Mitigate based on the actions being promoted. (FULL DISCUSSION AT D.2.3)
Support to Strengthen Value Chains	• Minimal direct impact on the environment but may result in cumulative, indirect beneficial or adverse effects as production or economic activity under targeted segments of the value chain increase. (FULL DISCUSSION AT C.2.5)	• Identification of environmental/social compliance and performance deficits in the processors' operations • Training or assistance to address these deficits (FULL DISCUSSION AT D.2.5)
Building Crop Production Infrastructure (including irrigation) **(see final row of table for general support to Irrigation)**	• Over-extraction of water • Salination or permanent degradation of irrigated soils • Contamination of surface and groundwater with agro-chemical leaching and run-off (SEE C.3, CONSTRUCTION SEG AND ANNEX A)	• Focus on occupational health and safety and fair labor practices including compliance with all host country requirements; • Appropriate sourcing of construction materials; and • Site-specific environmental and social review to inform site selection and design of specific mitigation measures, including identifying and addressing climate risks. (FULL DISCUSSION AT D.3; IRRIGATION ANNEX.)
Support for/Procurement of Seeds and Planting Materials	• Use of poor quality seed and planting materials can have a negative effect on crop yields and waste agricultural inputs. • Seed-borne fungal pathogens can	• Do not introduce invasive species • Use only seeds and planting materials that meet host country sanitary and phytosanitary standards • Use only species/varieties known to

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
	cause important diseases of crops. • Introduction/spread of Invasive species. • Pesticide use in seed treatment. (FULL DISCUSSION AT C.4.1)	be appropriate for the agro-climatic zone • Educate producers regarding safe handling of treated seed (FULL DISCUSSION AT D.4.1)
Support to Fertilizer Procurement or Use	• Surface water and groundwater contamination. • Crop damage. • Human health hazards. • Greenhouse gas emissions. • Particulate air pollution. • Acidification. (FULL DISCUSSION AT C.4.2)	• Use/Promote Fertilizers Consistent with 4R Principles and Within an Integrated Soil Fertility Management (ISFM) framework. • Planting cover crops. • Maintaining buffers and borders. • Conservation tillage • Drainage water (e.g., runoff) management. • Provide training on safe and appropriate fertilizer use. • Provide and require PPE. • Time application correctly • Store separately and safely • Procure quality products • Use particular care in the context of irrigation. (FULL DISCUSSION AT D.4.2)
Support to Crop Protection (e.g., pesticides, IPM)	• Improper use of pesticides: on human health, acute poisoning, cancer, reproductive and developmental harm, damage to organs and nervous system. On the environment: acute and chronic effects on non-target organisms, including beneficial species such as pollinators. • Biopesticides and biostimulants, while posing fewer risks than pesticides, can also have adversely affect human health and the environment.	• Plan for, resource and implement all components of safer pesticide use, including at least reduced-form IPM • *NOTE: Support to the procurement and/or use of pesticides on USAID-funded activities requires compliance with the Agency's pesticide procedures, 22 CFR 216.3(b).* (FULL DISCUSSION AT D.4.3)

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
	(FULL DISCUSSION AT C.4.3)	
Support for Tools and Mechanization	• Soil compaction and damage, leading to poorer crop yields • Air and soil pollution (including GHG emissions) • Risks to health and human safety. (FULL DISCUSSION AT C.4.4; ALSO SEE LIVESTOCK SEG)	• Consider use of animal traction and/or lighter equipment (e.g., hand tractor) • Strictly limit provision of land clearance/logging equipment • Strictly limit provision of pesticide application equipment • Store fuels and oils properly. • Maintain equipment/plan for maintenance. • Use PPE and teach safe operation. • Screen new tools and technologies. (FULL DISCUSSION AT D.4.4)
Support for Crop Production Innovation/Research and Development	• Impact of GM/GE varieties and containment facility research on food safety and animal feed (e.g., toxicity) • Potential for weedy or invasive persistence, unintended gene flow to other organisms, impact on non-target organisms. (FULL DISCUSSION AT C.5)	• Physical sampling should be conducted per a field manual or operating procedure addressing field team safety in addition to sample quality and integrity • Containment facility research should be supported with a documented, independently reviewed risk assessment to determine the risk level, and independent expert site audit to verify conformity of the facility with requirements (FULL DISCUSSION AT D.5)
Support for Mixed Farming Systems and Agroforestry	• Mixed farming systems involving intercropping: all general impacts of crop production, as above. • Mixed farming systems involving agroforestry: all general impacts of	For mixed farming systems involving intercropping: Appropriate mitigations for general crop production as specified above; also see D.1.7 for mitigations

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CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
	agroforestry; see Forestry SEG. • Mixed farming systems involving livestock: impacts of livestock, including health and pollution risks associated with manure; see Livestock SEG. (FULL DISCUSSION AT C.6; ALSO SEE USAID FORESTRY SEG)	attendant to polycropping. For mixed farming systems involving agroforestry: see Forestry SEG. For mixed farming systems involving livestock: • Properly store manure, whether liquid or solid, until the manure is field applied. Proper storage protects the manure from the environment, maintains its nutrient content, and reduces odor and insect infestations that can result from stored manure. • Identify appropriate crop fields where the manure will be applied. Manure application rates should be adjusted for soil type, soil analysis, and crop needs. • Rotate manured fields so that all of a farm's manure is not repeatedly applied to the same area. This reduces the potential for over-application of crop nutrients and subsequent nutrient losses. • Use good manure application techniques to stabilize the manure and manure nutrients in the soil, preferably by immediate incorporation of the manure into the soil. (FULL DISCUSSION AT D.6; ALSO SEE USAID LIVESTOCK SEG)

TABLE 1. SUMMARY OF CROP PRODUCTION ACTIONS, ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES		
CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
Support to Harvest, Post-Harvest, Logistics, Storage, Marketing and Food Processing	• Solid Waste Production. • Generation of Wastewater/Liquid Waste. • Energy Consumption, GHG Emissions, and Air Pollution. • Excessive water use. • Noise pollution and odors. • Consumer health risks. (FULL DISCUSSION AT C.7)	• Inspect to Identify EHS and Food Safety Deficits, Make Support Conditional on Corrections. • Promote Food Safety. • Research and apply relevant innovations in more sustainable harvest and post-harvest practices. • Review and apply as relevant the Food Processing RECP Briefing and Resource Guide. • Pest control. • Conduct environmental screening when introducing new tools and technologies. Identify relevant aspects of planned activities and mitigate appropriately, per mitigation recommendations above. "Relevant aspects" include: • Construction • Fuel storage of fuel • Energy consumption • Use of hazardous materials, including pesticides • Occupational safety hazards • Other generation of waste and pollution (FULL DISCUSSION AT D.7)
Support to Irrigation	• Potential for water use mismanagement • Water pollution from irrigation runoff • Changes to soil resulting from irrigation • Impacts associated with use of water pumping equipment	• Design based on needful baseline information and informed by local knowledge and appropriate ESIA • Irrigation management and water conservation • Maintenance of irrigation systems

TABLE 1. SUMMARY OF CROP PRODUCTION ACTIONS, ENVIRONMENTAL IMPACTS AND MITIGATION MEASURES		
CROP PRODUCTION ACTION	SUMMARY OF SELECTED POTENTIAL ENVIRONMENTAL IMPACTS	SUMMARY OF SELECTED POTENTIAL MITIGATION MEASURES
	• Impacts related to construction of water infrastructure • Impacts on health due to breeding vectors of disease • Impacts on the ecosystem • Social impacts pertaining to water rights (FULL DISCUSSION IN ANNEX 1.2)	• Capacity building for irrigation management, maintenance and water conservation • Preventing pollution and vector breeding by irrigation activities • Integrating ecological considerations into irrigation projects design and implementation • Engaging communities and taking social dynamics and potential for water conflicts into consideration (FULL DISCUSSION IN ANNEX 1.3)

C. POTENTIAL ENVIRONMENTAL AND SOCIAL IMPACTS OF CROP PRODUCTION PROGRAMMING AND THEIR CAUSES

This section describes the environmental and social impacts of crop production and associated activities along the value chain as follows:

- C.1 presents the overall impacts of crop production, with treatment of impacts in specific vulnerable landscapes, and of specific crops.
- C.2–C.8 describe the potential impacts of the most common categories of crop production programming. For the purposes of this document, these categories are as follows:
    - Developing and strengthening the crop production enabling environment
    - Building crop production infrastructure
    - Supporting inputs to crop production
    - Supporting crop production research and innovation
    - Supporting mixed farming systems and agroforestry
    - Supporting harvest and post-harvest storage, processing, and marketing
    - Integrating crop production with nutrition, disaster risk reduction, MSME support and disaster risk management
- C.9 is a cross-cutting discussion of the social impacts of crop production.

This structure is intended to allow expeditious identification of the potential impacts associated with specific crop production programming.

Figure 7. Farmers in Baliakandi, Bangladesh learn how to use low-cost, organic pesticides that save money while protecting crops and the environment. Photo Credit: Kipp Sutton, USAID

C.1 POTENTIAL ADVERSE IMPACTS OF AGRICULTURAL CROP PRODUCTION

C.1.1 GENERAL ADVERSE IMPACTS

Unless environmentally sound practices are followed, crop production can result in the following adverse environmental impacts:

Land Conversion, Change of Landscapes and Loss of Vegetation. Clearing of land for agricultural production can degrade and fragment landscapes, isolating animal populations, altering microclimates at forest edges, and disrupting ecosystem services. Crop production can contribute to deforestation; desertification; grassland degradation; encroachment into marginal lands, hills, wetlands, shallow lakes, and protected areas; and adversely impact biodiversity and natural habitats.

Clearing of forest, particularly mature forest, can result in increased soil erosion, loss of biodiversity, destruction of carbon sinks, release of GHGs decreased rainwater infiltration into soils and aquifers, changes in the soil micro-biome, and increased soil temperatures.

A key consequence of unsustainable agricultural intensification is landscape simplification where once heterogeneous landscapes become increasingly homogeneous with fewer crop types and non-crop habitats. Landscape simplification can exacerbate biodiversity losses and adversely impact ecosystem function.

Figure 8. Legal planting: USAID supports sustainable agroforestry in former coca-producing regions to produce legal sources of income through licit crops, such as cacao, coffee, banana, and local timber trees. Photo credit: USAID

Introduction of Non-Native Species. The unintentional or intentional introduction of new crops into mono-cropping, agroforestry, cover crops, hedges, windbreaks, and riparian buffers presents risks to native species and ecosystems. Intentionally introduced non-native species can be disruptive or invasive. Introduced exotic species may spread diseases, out-compete native species for resources, or interbreed with native species. The possibility of unintended harmful consequences of an introduced species has become a key issue with regard to GE organisms.

Soil Erosion. Soil erosion can be caused by over-tillage, growing crops in the wrong way or place, not vegetating or otherwise stabilizing the banks of irrigation ditches, deforestation, or draining of wetlands. As soils erode and lose organic matter and nutrients, less rainfall is absorbed and excess water runs off. This runoff removes the most fertile topsoil necessary for crop production and can have serious off-site consequences, including gully formation, landslides, siltation and sedimentation of water bodies, downstream flooding, and damage to productive infrastructure. Wind erosion can have significant negative impacts on soils in many areas, particularly in dry areas where vegetation has been removed. See Box 2 for additional detail on wind erosion.

BOX 2. SOIL EROSION FROM WIND

Wind can cause damaging soil erosion in landscapes that are generally flat, arid or semi-arid areas, and where the soil becomes dry, loose and is finely granulated. Wind erosion damages land and natural vegetation by removing soil from one place and depositing it elsewhere. The movement and deposition of transported soil particles is also an air quality problem and can result in land and water pollution, depending on where the soil particles are deposited.

Soil erosion from wind results in losses of soil fertility, as the finest soil particles holding the most nutrients are removed first. Wind erosion can become a particularly serious problem for crop production in areas where: the soil surface is relatively smooth and natural vegetation is sparse or has been removed, the fields are large with few obstructions to reduce the force of the wind, and there is sufficient wind to initiate soil particle movement.

Any time there is dry, bare, unprotected soil, wind erosion can occur. Tillage used to prepare fields for planting can create soil conditions susceptible to wind erosion by breaking down soil aggregation, destroying crop residues, and drying the soil.

Reduction in Soil Fertility. Soil fertility is dependent on three major crop nutrients (nitrogen (N), phosphorus (P), and potassium (K)), as well as other macro-nutrients (e.g., calcium, sulfur), various trace elements, and organic matter content. Productive soil contains sufficient quantities of each of these elements for optimal crop plant growth. However, these elements can be removed from the soil by repeatedly cropping without adding fertilizers, leaching due to rainfall, using too-short fallow periods, and burning of crop residues. As stated above, decline in soil fertility often occurs with loss of top soil that is eroded due to decreased vegetation growth, while poor soil fertility and increased erosion lead to decline of vegetative growth.

Sedimentation of Water Bodies. Eroded topsoil from agricultural fields can be carried by runoff or wind into water bodies. Once in slower-moving water, soil particles (or sediment) settle, altering the composition of the bottom terrain, water chemistry, and depth. This sedimentation can bury fish spawning sites and streambed nutrients, disrupt fish movements, and damage bottom-dwelling populations. Sedimentation in wetlands and coastal areas can reduce productivity, decrease marine populations, and increase the likelihood of flooding in adjacent areas. Very fine particles (silt) may remain in suspension, resulting in high turbidity, which also had adverse impacts on aquatic life and human use.

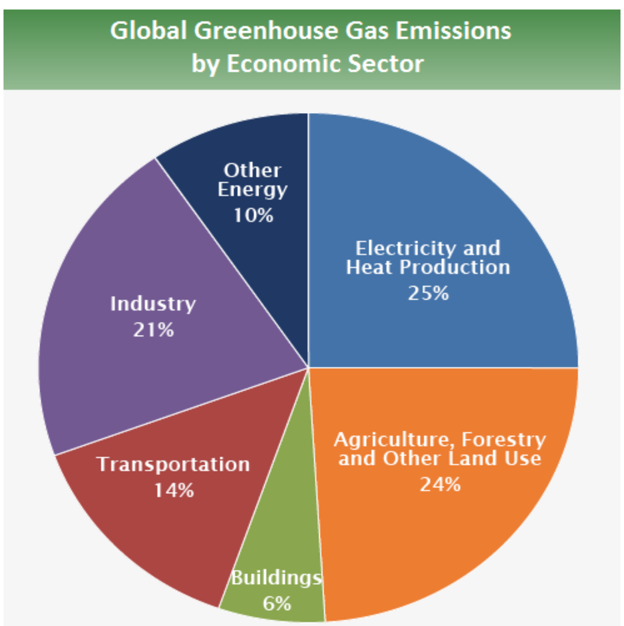
Large-scale sedimentation can: reduce channel capacity, thereby impairing river shipping and transport and/or increasing downstream flooding. It can also reduce the holding capacity of dams, adversely impacting flood control, hydropower production, and reservoir functions.

One remedy for sedimentation, dredging, is an expensive and complex process that must be repeated at intervals and can further degrade or destroy aquatic and riparian ecosystems.

Reduction in Surface and Groundwater Quality. The misapplication of pesticides, fertilizers or manures can result in the migration of nutrients or harmful residues from a farmer's field to local surface and groundwater water sources, causing environmental harm and adversely impacting human health. For example, nutrients from fertilizers may cause nutrient loading in local water bodies, resulting in degraded water quality; altered water chemistry; reduced wildlife, fish and mollusk populations; and toxic algal blooms. Moreover, such reductions in water quality can impact other farmers and the use of water bodies for drinking water, sanitation, fishing, aquaculture, recreation, and tourism.

Climate change and GHG Emissions. Agriculture both contributes to climate change and is affected by climate change. Each stage of the crop production value chain releases GHGs into the atmosphere; with the IPCC estimating that "Agriculture, Forestry and Other Land Use" accounts for about a quarter of global emissions, and transport and processing along the agriculture value chain adding to the total. About half of GHG emissions from crop production are from crop residue burning, though manure and synthetic fertilizers, among other actions, make a significant contribution (see Figures 9 and Figure 10 below).

However, agriculture can also result in net carbon sequestration in soils and biomass.



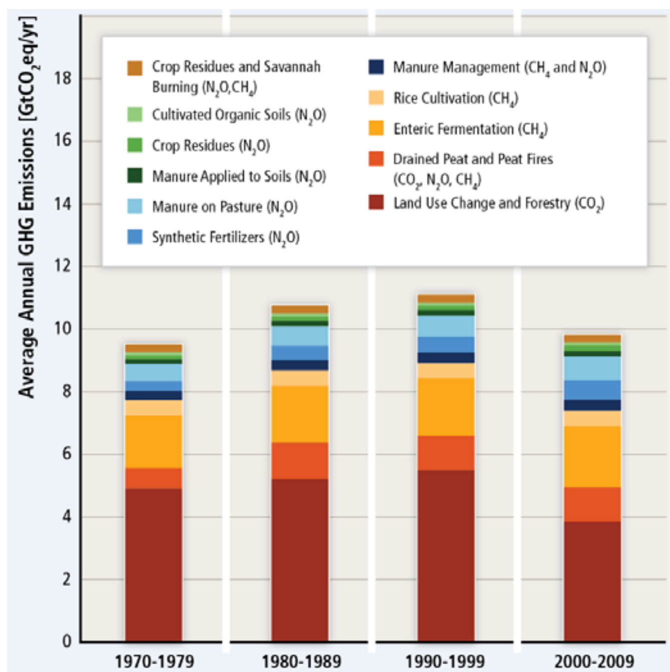


Figure 9. Contribution of Agriculture to Global GHG Emissions; Contributions of Agricultural and Land-use Activities to Agricultural Sector Emissions.
Source: IPCC (2014);

At the farm level, emissions vary significantly depending on the crops grown, farming practices employed, and natural factors such as weather, topography, and hydrology.

Some countries, particularly in Africa, still have relatively low agricultural emissions. Growth in agricultural emissions are anticipated to be greatest in Asia and sub-Saharan Africa, which are estimated to account for two-thirds of the increase in the global food demand over first half of the 21st Century. The production of vegetable oils and animal products (i.e. products with a high GHG intensity) are expected to grow the most among agricultural outputs. Although minor for each individual farmer, cumulatively, agricultural pollution can be significant on a regional, national or global scale.

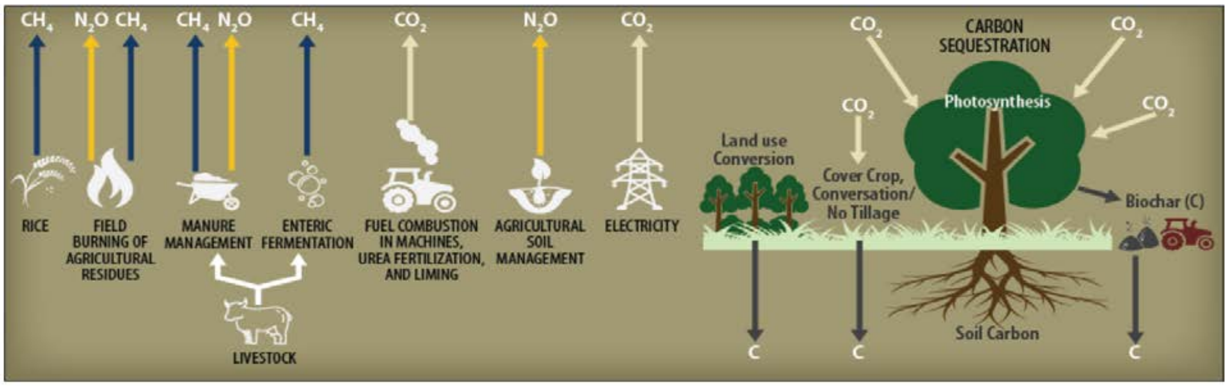


Figure 10. GHG Emissions from Farming Activities and Carbon Sequestration in Agricultural Soils
Source: (Congressional Research Service, 2018)

C.1.2 POTENTIAL IMPACTS OF CROP PRODUCTION IN SPECIFIC VULNERABLE LANDSCAPES

Upland Crop Production can result in soil erosion when not properly managed. Steeper slopes are particularly vulnerable when vegetation is removed and soil is exposed.

One of the most distinctive features of the landscape in many mountainous regions is agricultural terraces. Terraces play an important role in soil conservation by reducing the length of the slope of the cultivated land, thereby reducing water and soil runoff. Because terracing has a significant potential to slow down land degradation and improve quality of life of local populations, it is usually encouraged and is discussed in Section D of this document. However, failed terraces create severe and sometimes irreversible problems for the landscape. Terracing requires careful long-term planning in which political and social stability plays a vital role (Duprez, 2016).

Crop Production in Riparian Zones. Riparian areas include streams, stream banks, and wetlands adjacent to streams. The riparian zone is critical to the health of every stream and its surrounding environment.

Crop production can adversely impact riparian areas:

- Irrigation requirements may lead to unsustainable water withdrawals from streams. Satisfying crop production water needs can lead to changes in the hydrology and sediment transport of streams (hydro-modification) (See Annex 1: Irrigation).

- Crop production can lead to vegetation removal, downstream water changes, and increased erosion of stream banks. Farmland can also be lost where erosion occurs. When upland watershed conditions are degraded, heavy, sediment-laden runoff can flow over or through riparian plants and move directly into river channels (Bellows, 2003).
- Fertilizers and pesticides can negatively impact water quality (Zaimes, 2007). The use of agricultural chemicals in riparian zones is of major concern worldwide because of negative impacts to aquatic ecosystems.

Riparian areas are very commonly used for dry season horticulture because of the soil quality and easy access to water. As climate change is expected both to increase extreme rainfall events and the incidence of drought, production and people in these areas face both risks of floods and/or drying of streams.

Wetlands Crop Production. Extensive environmental damages and loss of ecosystem services (see C.9.4) can occur when natural wetlands are drained or hydrologically altered and converted to farmland:

- As wetlands are drained or hydrologically altered, the results can be habitat fragmentation; changes in species composition (as wetlands species are replaced by upland or exotic species); loss of large, wide-ranging species; loss of genetic integrity (when isolated habitats are too small to support viable populations); reduced populations of interior species (that can only reproduce in large tracts); and increased numbers of competitor, predator, and parasite species tolerant of disturbed environments.
- Wetlands can improve watershed water quality by processing pollutants, but this capacity can become compromised by fertilizer, manure, and pesticide pollution, leading to wetland degradation and degraded groundwater and downstream surface water quality.
- Wetlands often provide significant flood control functions; this is significantly degraded or lost when wetlands are converted to farmland.
- The loss of coastal wetlands and their associated functions has, in many areas of the world, led to losses of shoreline and increased sediment movement into estuaries (Walters, n.d.), as well as significant degradation of fisheries.

Crop Production in Coastal Low-Lying Lands and Wetlands. Saltwater intrusion in coastal aquifers and freshwater wetlands is a serious problem that limits crop cultivation. Saltwater intrusion in wetlands result from several factors including sea-level rise, surges from coastal storms that flood the land with seawater, and droughts that can increase the concentration of salt in brackish water. Saltwater intrusion in aquifers can result from saltwater intrusion in the surface waters that recharge the aquifer, and/or when groundwater is pumped from aquifers with hydraulic connection to the sea. Under pumping, induced gradients may cause the migration of salt water from the sea towards a well, making the groundwater unusable (Kibria, 2014).

C.1.3 POTENTIAL ENVIRONMENTAL IMPACTS ASSOCIATED WITH SPECIFIC CROPS

Note*: this section presents potential impacts that are typically of most concern for a set of important crops. These impacts will vary with the specific environmental and social context, and the techniques and technologies used. Impacts of value-added agricultural processing and storage for these crops is addressed in Section C.7. Impacts of biotechnology are addressed in Section C.5.*

Bananas and Plantain. The environmental risks of banana and plantain production stem from monocropping, deforestation and erosion, improper use of agricultural chemicals, and poor disposal of plastic and degradable wastes.

Cocoa (Cacao). An estimated 70 percent of world cocoa production is grown by smallholders, largely in low input, low-intensity agricultural systems. Cocoa grows best in humid tropical conditions and is therefore mostly grown in the tropical rainforest zones of the world. Cocoa has the smallest environmental impact of all the tropical cash crops as it requires some shade and forest cover and has few inputs. However, widespread clearing of forests for intensive cocoa production on large plantations can result in ecosystem degradation. Intensive large-scale cocoa production can also result in reductions in biodiversity and soil fertility; soil erosion; stream sedimentation; and health and environmental problems associated with agrochemical application and runoff (International Cocoa Organization, 1998.)

Coconut. Commercial monoculture farming of coconut presents a set of concerns. As the coconut tree ages, it becomes less productive. This motivates farmers to plant more and more coconut trees to maintain a constant stream of product. Replacing native plants and biodiversity to meet the demand for coconuts can degrade soil, which is often already of poor-quality in coconut-growing areas. Farmers then turn to fertilizers, which require careful use to prevent leaching given sandy soils favored by coconut.

Coffee. Sun-grown coffee (*Robusta*) is usually grown at lower elevations as a monocrop, while shade grown coffee (*Arabica*) is grown at higher elevations and mimics the way coffee grows naturally, underneath a forest canopy. Without implementing soil conservation practices, sun cultivation of coffee can lead to loss of forests, while shade-grown coffee usually does not lead to major deforestation. To be classified as shade grown coffee, taller trees that provide a canopy must be planted throughout the fields (Chudnovsky, 2017). (*Note: Agroforestry is addressed in the USAID Forestry SEG.*)

Cotton. Cotton is mostly grown in monoculture and is considered the most pesticide-intensive of the major crops. If cotton is cultivated intensively in dry areas, it requires large amounts of water for irrigation, which can cause soil salinization and hence degrade soil fertility.

GM *Bacillus thuringiensis* (Bt) cotton—an insect-resistant transgenic crop (see A.4.2)—has influenced the production of cotton worldwide. It can be considered a more environmentally friendly crop because fewer pesticides are used and it is more efficient than non-GM cotton, producing higher yields on smaller plots of land and thus conserving resources (University of Montana, n.d.). However, reports have already identified field-evolved resistance of populations of bollworm, *Helicoverpa zea* (Boddie), in the southeastern US to Bt cotton. To combat this resistance, a strategy was developed that crossed transgenic Bt plants with conventional non-Bt plants and then crossed the resulting first-generation (F_1) hybrid progeny and sowed the second-generation (F_2) seeds. Further emergence of resistance remains a concern.

It should be noted that about 1 percent of cotton on a global basis is grown according to organic standards utilizing methods and materials that have a low impact on the environment. Organic cotton was grown in 20 countries by approximately 219,000 farmers worldwide in 2010-11, mostly in developing countries.

Flowers. Flower production typically entails extensive use of agrochemicals— as non-edible crops, flowers are usually exempt from regulations on pesticide residues— which may negatively affect the air, soil, and water supply. As a high-value crop, flowers must be irrigated to ensure reliable production. Use of water for flower production may divert water from other uses and users. (See Annex 1.2.1)

Fruits and Vegetables. Environmental impacts associated with horticultural production include pollution and contamination of soil, water, air, and food resulting from the use of farm chemicals. Fruit and vegetable production under poor management practices can be result in disturbances to ecosystems, the destruction of wildlife habitats, the reduction in wildlife species, and the loss of biological and genetic diversity of plants and animals (Stringer, 1998). Packaging of perishable horticultural crops can also contribute to the higher environmental impact of these crops (Zarei, Kazemi & Marzban, 2017).

Legumes other than soybeans such as beans, peas, lentils, cowpeas and chickpeas may have benefits for agricultural sustainability. By fixing nitrogen in the soil, legumes allow the sequestration of carbon in soils and reduce fossil fuel energy inputs to crop production by reducing the need for nitrogen fertilizers. In addition to serving as a fundamental, worldwide source of high-quality food and animal fodder, legumes contribute to the reduction of GHG emissions as they release five to seven times less GHG per unit area compared to other crops (Stagnari et al. 2017).

Legumes can also be economically competitive crops. Due to their environmental and socioeconomic benefits, they can be introduced in modern cropping systems to increase crop diversity and reduce use of external inputs. They also perform well in conservation and intercropping systems, which are very important in developing countries as well as in low-input and low-yield farming systems.

Maize has become the principle staple food crop produced and consumed by smallholder farm households globally. Maize crops can have adverse impacts on soils if farmers leave soil exposed during much of the growing season. Maize is also a relatively high-input crop with respect to water use, fertilizer (especially nitrogen) needs, and often crop-protection chemicals. Environmental concerns, such as biodiversity loss, are commonly cited for farming systems in which maize is grown as a monoculture.

Millet & Sorghum are more drought-tolerant crops than maize and can exhibit relatively fewer of the environmental impacts commonly associated with more intensively-cultivated crops like maize, such as fertilizer runoff, pesticide contamination, or water depletion. Both of these crops are overwhelmingly grown by smallholder farmers, and the economics of this production are such that few if any chemical or irrigation inputs are utilized. However, the tendency to grow sorghum and millet on marginal and

Note: *all USAID-funded projects or programs involving GM/GE organisms must follow ADS 211 procedures and guidance. See Section D.5 for mitigation measures.*

In addition, USAID support for cotton is a restricted by law. The "Bumpers Amendment" states that: "None of the funds to be appropriated to carry out chapter 1 of the Foreign Assistance Act of 1981 may be available for any testing or breeding, feasibility study, variety improvement or introduction, consultancy, publication, or training in connection with the growth or production in a foreign country for export if such export would compete in world markets with a similar commodity grown or produced in the United States.

heavily-sloped lands does pose environmental risks—including soil degradation and erosion—that can be mitigated through the adoption of best practices (Slakie et al., 2013).

Mushroom Cultivation. Mushroom production normally has substantially less adverse environmental impact than other agricultural industries. Mushrooms have the ability to consume discarded organic materials (lignocellulose wastes) that may help control pollution. However, disinfection is particularly important in mushroom production and chemical disinfectants that can potentially be considered pesticides by USEPA are regularly used (Laufer, 2017, Chang & Wasser, 2017, Sonnenberg, n.d.).

Palm Oil has been linked to destruction of rainforests and associated fauna. Development of new large-scale oil palm plantations, particularly in Southeast Asia, coupled with smallholders expanding their farms to meet the rising demand for palm oil, has resulted in significant deforestation. The removal of thousands of acres of rainforest threatens the rich biodiversity in these ecosystems, along with the habitat of species such as the orangutan, which is critically endangered.

Additionally, deforestation releases carbon into the atmosphere, speeding up climate change. In the tropics, tree roots anchor the soil and deforestation removes this important structure, allowing heavy rains to wash away nutrient-rich soil. In addition, if palm oil is cultivated on cleared and drained peatlands, large amounts of GHGs are released when peat decomposes or is burnt, and drained peatlands subside (sink) and eventually become non-productive.

While the global palm oil market creates an opportunity to bring many communities out of poverty, land rights conflicts have left many local communities displaced. The resulting conflicts, loss of income, and dependence on large plantations have had a significant impact on social welfare (Green Palm Sustainability, n.d.).

Rice production in paddies usually requires large flooded areas. Under these conditions, many GHGs are generated, contributing to climate change. Rice production can also increase levels of nutrient and pollutant loads in the form of pesticides and fertilizers that damage and alter wetlands.

Roots and Tubers. Tropical roots and tubers include cassava, sweet potato, yams and taro. Tuber crops are vegetatively propagated and multiplied. Cassava is a major staple food and the third largest source of food carbohydrates, providing a basic diet for over half a billion people. Cassava and other tubers are often produced by smallholder farmers on marginal soils and the economics of this production are such that few if any chemical inputs are utilized. However, expanded production has resulted in deforestation, often via slash-and-burn technique and eliminated or shortened fallow periods. This contributes to soil erosion, depletion of soil nutrient supply, and loss of biodiversity (Mohan, Prasannakumary & Nair, 2016).

Soybean. Soybean is the world's most important vegetable protein crop, and its wide and expanding cultivation in many countries, as well as the international nature of its market, exemplifies the potential environmental and socio-economic impact of global markets and global agricultural policy. Soybean plays an important role providing an alternative source of protein to humans and for livestock and poultry production. As a nitrogen-fixing leguminous plant, soybean works well for many farmers as a rotation crop with cereals in mixed farming systems and may reduce the need for nitrogen fertilizer. However, much of the rapid increase in soybean production for export has been achieved by expansion into natural habitats and encroachment into fragile ecosystems. This can lead to large-scale land degradation and deforestation causing a severe loss of natural resources and ecosystem services, which threatens wildlife and biodiversity.

Nursery, Greenhouse, & Hydroponic Production. In nursery production, plastic has the highest relative environmental impact, amounting to approximately 80 percent of the value of the total carbon footprint of the nursery.

Greenhouse production includes greenhouse construction, irrigation equipment, water use, and the use of fertilizers and pesticides. Its relative impacts versus open-field production are not well-characterized. However, the following can be noted:

- Most of the environmental impacts of greenhouses occurs from heating and cooling systems (Muñoz et al, 2008).
- Fertilizer impacts are the highest in open field production.

Hydroponic production of horticultural crops in a controlled environment is generally considered more environmentally friendly (Beccaro et al., 2014).

C.2 POTENTIAL ENVIRONMENTAL IMPACTS OF ACTIONS THAT DEVELOP AND STRENGTHEN CROP PRODUCTION ENABLING ENVIRONMENT

Note: *See A.6 for a general discussion of the enabling environment for crop production.* ***Infrastructure*** *and support for* ***Innovation/R&D are*** *often considered aspects of the enabling environment, but are addressed separately, in sections C.3 and C.5, respectively.*

C.2.1 POTENTIAL IMPACT OF SUPPORTING AGRICULTURAL POLICY

Supporting/Strengthening Agricultural and Related Policies. In general, agricultural policies can be environmentally beneficial, adverse, or mixed in their effect. Predicting impacts of proposed agricultural policies on the environment is challenging as effects are indirect, and a given policy is usually just one factor driving behaviors of producers and/or other actors along the value chain.

This said, the starting point for identifying such impacts is to ask what the effect on crop production (including, but not limited to scale, intensity, crop mix, and geographic distribution) and other segments of the value chain will be *if the policy works as intended.* Then, identify the environmental effects likely to follow from these changes. For example, a policy that is intended to expand production of a given cash crop may foreseeably result in land conversion, increased use of water or other inputs, and potentially displace food security crops. Environmental and social consequences flow from each change.

It is then equally critical to identify potentially perverse or unintended effects of the proposed policy---i.e. to ask how the policy might incentivize actors along the value chain to act in ways that are counter to or simply unrelated to the effect the policy is seeking to achieve. (For example, bounties placed on invasive pests have resulted in deliberate breeding of the pests in question (Dubner, 2012)). For these unintended actions, too, environmental effects should then be considered.

Agricultural Taxes and Subsidies are a particular class of agricultural policy. They can include taxes levied on key export commodities, subsidies on important national food items such as maize, and price interventions on critical inputs such as inorganic fertilizer. Agricultural taxes and subsidies are specifically intended to create economic rewards or penalties for specific production decisions by farmers, or for economic decision-making by other actors along the value chain. These decisions indirectly impact the environment, sometimes consequentially. The basic approach to understanding potential impacts of taxes and subsidies is as for policies, above.

C.2.2 POTENTIAL IMPACTS OF SUPPORT FOR TRADE AND INVESTMENT

The theory of trade is that both trading partners gain economically from trade by specializing in the goods that they can produce most efficiently. However, market transactions and the economic benefits that accrue to individual actors may not reflect the environmental or social costs associated with production of the crop or crop product in question. For example, when crop production expands to serve an export market without corresponding focus on environmentally sound production practices, adverse environmental impacts are likely, particularly in countries where capacity to enforce environmental management standards is low. An example is palm oil production for export described in Section C.1.3.

Similarly, promoting investment can bring technological innovation, increases in competitiveness, improvements in efficiency, and transfers of tangible and intangible resources such as new forms of organization, management, and marketing. However, the same concerns apply: when investment increases the scale of production or results in a switch to more input-intensive production without corresponding focus on environmentally sound production practices, adverse environmental impacts are likely, particularly in countries where capacity to enforce environmental management standards is low.

C.2.3 POTENTIAL IMPACTS OF SUPPORT FOR EXTENSION SERVICES

Strengthening and improving access to extension services and agricultural knowledge is intended to have positive impacts on farmers' income and/or food security.

Whether extension services present environmental or human health concerns depends on the types of actions being promoted:

- Extension services can, for example, be focused on sustainable land and soil management techniques intended to sustain or increase long-term farm productivity. These are intended to be environmentally beneficial. However, they can present the set of concerns and considerations attendant to these practices, as outlined in D.1.4–D.1.7. (For example, health risks presented by use of insufficiently composted manure; the risks of poorly designed, constructed or maintained terraces.)
- Extension services can also be focused on intensification, adoption of cash crops or other endpoints that involve increased use of fertilizers, pesticides, or mechanization with a resulting set of impacts outlined in C.4.2–4. Extension services with this orientation may also present the risk of stimulating land conversion and displacement of subsistence-farmer tenants (see C.9).

The above discussion assumes that extension services are promoting crops/varieties and approaches that are proven *in practice* to be appropriate to the agro-ecological zone (see A.4.1) and farmer capabilities. Failure of extension services to follow these basic requirements of good practice presents a potentially serious set of environmental risks.

C.2.4 POTENTIAL IMPACTS OF SUPPORT FOR DATA, INFORMATION, AND COMMUNICATIONS SYSTEMS

Data and information can help farmers make decisions that lead to increased yields and profits. For example, market information allows producers to determine when and where to sell their crop and accurate weather and pest outbreak forecasts allow farmers to practice adaptive, rather than reactive, farm management.

Historically, developing-area producers and value chains have been information-poor. Mobile technology, among other developments, have potential to change this, and USAID and other donors frequently support efforts to improve agricultural market and technical information.

Provision of information *per se* rarely presents environmental or social impacts of concern. To the extent that information helps farmers use productive resources more efficiently, information provision is environmentally beneficial.

However, information can be provided that is likely to result in a response from a producer, and such responses may present environment or health risks. For example, information regarding a pest outbreak could foreseeably lead to preventative spraying. In this case, failure to provide information about how to safely and appropriately respond to the outbreak makes it more likely that environment and/or health will be adversely impacted.

C.2.5 POTENTIAL IMPACTS OF SUPPORT TO STRENGTHEN VALUE CHAINS

A value chain (see A.5) is a set of linked activities that work to add value to a product, such as processing groundnuts into peanut butter. It consists of actors and actions that improve a product while linking commodity producers to processors and markets.

"Soft support" to value chains. Many typical value chain support activities have minimal direct impact on the environment, such as business literacy training for farmers and small processors, linkage and partnership development between actors in different value chain segments, building farmer and water user associations, and marketing support. However, these activities have the potential to result in cumulative, indirect beneficial or adverse effects as production or economic activity under targeted segments of the value chain increase.

As such, indirect impacts of these activities are the same as the impacts of direct support to production and to other specific value chain segments; see the appropriate sub-section above and below.

Direct support to value-added activities. Strengthening value chains can include direct support to actors and enterprises providing logistics, transportation, packaging, food processing, and storage. Impacts of value-added food processing activities are addressed in Section C.7. The potential for pest damage in stored commodities may necessitate the use of pesticides; adverse impacts of pesticide use are addressed in Section C.4.3. Energy use in agricultural production and processing is addressed in Section C.4.6.

C 2.6 POTENTIAL IMPACTS OF SUPPORT FOR CLIMATE ADAPTATION PLANNING

Planning for adaptation has no direct environmental impacts—but can have significant indirect impacts, when planned measures are implemented. These impacts will depend on the nature of the measures/actions being planned; there are no "one-size fits all" adaptation measures, as (1) projected climate change impacts vary significantly, as do institutionally, technically, and financially feasible adaptation measures. For example, adaptation measures can include strategies such as early planting, but also more structural interventions such as the building of water infrastructure. Potential impacts of the specific adaptation measure(s) must be identified with reference to this or other SEGs, and with respect to the particular environmental and social context.

C.3 POTENTIAL IMPACTS OF BUILDING CROP PRODUCTION INFRASTRUCTURE

Electricity, roads and storage structures, among other infrastructure, are significant determinants of agricultural productivity and the ability of crop production value chains to function efficiently (Llanto, 2012). Irrigation systems are likewise key to productivity, and may require building structures such as dams, canals, and boreholes.

Environmental and social impacts of infrastructure during construction and operation can be significant and adverse; Information on these impacts is found in the Construction and Rural Roads SEGs and, for irrigation, in Annex 1.

C.4 POTENTIAL IMPACTS OF SUPPORTING INPUTS TO CROP PRODUCTION

C.4.1 POTENTIAL IMPACTS OF SUPPORT FOR/PROCUREMENT OF SEEDS AND PLANTING MATERIALS

Seeds and Planting Materials. Developing-area producers and particularly smallholders often use or purchase poor quality seed and planting materials from uncertified sources. Using low-quality seeds and planting materials can have a negative effect on crop yields and waste agricultural inputs. Seed-borne fungal pathogens can cause serious diseases in crops, while poorly cleaned seeds can introduce weeds or "off-types"—i.e. seeds that do not produce the intended crop variety.

Seed Importation. Importers of seed into a country must comply with local regulations and applicable legislation. Invasive plant seeds are often distributed by humans, knowingly or unknowingly. Invasive species can have significant adverse impacts on the economy, human health, and biodiversity.

Seed Production Including Seed Diversification, Multiplication, and Quality Assurance. Seed diversification and quality assurance involves technical assistance and capacity building to improve the seed certification and multiplication systems that make seeds and planting materials higher quality and more consistent. Seed production is expected to have a positive impact on the environment when done in combination with comprehensive land use management by increasing productivity on agricultural lands, potentially reducing the need to clear more land for agricultural production. The activity may also reduce the number of non-target seeds or off-specification seeds in seed lots, and, therefore, reduce the amount of non-native or exotic seeds sown into fields.

Commercial seed multiplication involves the operation of seed farms (often irrigated), and almost always entails use of fertilizers and pesticides (agro-chemicals). Commercial seeds are typically pesticide-treated. The use of agro-chemicals, particularly in the context of irrigation, presents a set of concerns outlined in Section C.4.2 and C.4.3 and in Annex 1.

Improved Seed. Increasing agricultural crop production relies heavily on improved seeds and their availability. Scientists and agronomists worldwide are working to develop seeds that are higher yielding, more nutritious, and drought and climate-resilient.

> ***Note****: Improved seed may be GM/GE. The impacts of GM/GE crops are addressed in Section C.5. any USAID-funded project or program which involves the use of GM/GE organisms must follow ADS-211 procedures and guidance (see Section D.5).*

Pesticide Use in Seed Treatment. Seeds that are pre-treated with pesticides are not considered pest-control products under the US Federal Insecticide, Fungicide and Rodenticide Act (FIFRA). However, risks associated with treated seed are related to exposure. Adverse health and environmental impacts due to exposure may result from using seed for animal feed, food or oil purposes; improperly storing or composting seed; not following minimal planting depth requirements; spilling treated seed; not following required restrictions; and not using necessary personal protective equipment (PPE) when handling treated seed. Adverse health and environmental impacts of pesticide use is addressed in Section C.4.3.

> ***Note****: One of the common classes of pesticide used for seed treatments are neonicotinoids. Neonicotinoids are systemic insecticides which move throughout all plant tissues (including new growth) making them toxic to any insects (and potentially other organisms) that feed upon the plant. As the treated seed sprouts and grows, the neonicotinoid in the seed coating is taken up and translocated to all parts of the plant. While effective against pests which attack young plants, use should be driven by the existence of an economic pest and must be part of an integrated pest management program. If no pests are present, the treatment of seeds has little value. However, seeds are routinely treated with neonicotinoids in developed countries, regardless of pest pressures or field histories. From an environmental risk stand point, note that neonicotinoid insecticides are very water soluble, which makes aquatic ecosystems and associated organisms particularly vulnerable to this class of pesticides. Furthermore, there is clear consensus that neonicotinoids are toxic to bees, so care should be taken to minimize potential exposure.*

Seed and Disaster Mitigation/Seed Security. Emergency seed aid is a common example of emergency agricultural assistance that seeks to accelerate farmers' recovery from crises, such as drought or short-term conflict, aiming to help them continue with crop production in the short-term, and reduce vulnerability to future stress. Improved seed is commonly sought by seed aid practitioners. Consideration must be given to whether introduced modern varieties are adapted to the local agro-ecologies and/or low-input conditions.

C.4.2 POTENTIAL IMPACTS OF SUPPORT TO FERTILIZERS PROCUREMENT AND/OR USE

Impacts of fertilizers on the environment vary depending on the type, application, and storage of the fertilizers. Impacts of fertilizers may include:

- *Surface water and groundwater contamination.* Over-application can lead to runoff into surface waters or leaching into groundwater, particularly in sandy soils. In certain conditions, even small amounts of over-application of phosphorus can lead to harmful algal blooms in waterways that reduce oxygen and kill in-stream flora and fauna.

- *Human health hazards* Fertilizer contact with bare hands may cause skin irritation and ingestion may be poisonous. Inappropriately stored fertilizer is a health hazard, as some can release toxic fumes. Phosphorous fertilizers may contain Cadmium and other heavy metals; uptake by plants/biomobility of these metals is complex, and the risk of accumulation in soil and plants varies. . Children who ingest water contaminated with nitrate may develop blue-baby syndrome or methemoglobinemia.
- *Crop damage.* Fertilizer application at inappropriate times or over-application is not only wasteful but can damage crops. Leaf scorch resulting from over-fertilization is referred to as "fertilizer burn" and is usually caused by excess nitrogen salts.
- *GHG emissions.* Fertilizer mismanagement can also contribute to GHG emissions, as soil microbes in areas of application produce nitrous oxide (N_2O). The addition of natural or synthetic fertilizers and wastes to soils represents the largest GHG source in agriculture, making up 65 percent of agricultural emissions globally. Manure used as fertilizer also releases GHG. However, in under-fertilized areas, fertilizer may contribute minimally to GHG emissions.
- *Particulate air pollution.* Particulate matter emissions of solid fertilizer compounds are primarily generated as windblown dust during broadcast application. According to WHO, fine particulate matter with a diameter of less than 2.5 micrometers (PM 2.5) is particularly harmful to health, because the particles can penetrate deep into the lungs and cause cardiovascular and respiratory diseases.
- *Acidification.* Nitrogen fertilizers can also contribute to soil acidification. Acid soils have lower availability of trace elements and can adversely affect the development of nitrogen-fixing legumes.

C.4.3 POTENTIAL IMPACTS OF SUPPORT FOR CROP PROTECTION, PARTICULARLY PESTICIDES

Most crop protection methods other than pesticides (see discussion of IPM in D.1.6) present little environmental or health risk. Improper use of pesticides (defined in A.4.6), by contrast, can present very significant environmental and human health risks. These risks include:

- Human health. Acute poisoning, which can be fatal; and chronic effects resulting from sub-acute exposures, including but not limited to cancer, reproductive and developmental harm, and damage to organs and the nervous system.
- Environmental. Acute and chronic effects on non-target organisms, including beneficial species such as pollinators.

Risks are complex and depend on the organism-specific toxicology of the pesticide, the amount and frequency of exposure, age (e.g. children are especially vulnerable), the exposure pathway, the environmental characteristics of the application area, and many other factors.

While pesticide residues in food receive significant attention, the use of "traditional" commercial pesticides on crops is fundamentally dispersive, with pesticide residues affecting the wider environment, such as air and surface water, as well as humans and wildlife:

> "*When a pesticide is applied directly to a target pest the whole site is affected including crop plants, soil organisms and, potentially, humans and wildlife in the immediate area. In addition, part of it goes to the air or to surface waters, due to emission or drift. Once on the target site, the pesticide may "drain" into*

surface waters or volatilize into the air. From the air it may deposit on humans, wildlife or plants or on the soil. From the animals or plants where it was applied the pesticide may leak into groundwater. Pesticides in surface water may get into aquatic organisms, and by sedimentation into other organisms that remain in the sediment. The persistence of the pesticide depends on its physical and chemical properties (partition coefficients, degradation rates, deposition rates) and the characteristics of the environment. Climate characteristics also play a role in persistence" (WHO, 2008).

Agricultural farm workers are the group in the crop production value chain who experience the highest pesticide-related risks. However, residents of farming communities are generally exposed to pesticides through spray drift, contact with treated areas, and potentially via drinking water. The general public can be exposed to pesticides via residues in food.

The choice of pesticide makes a significant difference to risk. For this reason, designated "minimum risk pesticides" are exempted from US regulation under FIFRA. However:

- Biopesticides (see A.4.6), while commonly considered to have fewer risks, are not minimum-risk pesticides and can be hazardous to human health and to the environment. Commercial biopesticides and biostimulants regulated by USEPA under FIFRA are pesticides.
- Artisanal mixtures used as pesticides cannot be assumed to be intrinsically low risk: some of the ingredients used in preparation of artisanal mixtures can be hazardous to human health and to the environment.

Note that microorganism derived biostimulants (see A.4.4) may be defined by USEPA as pesticides or be subject to biosafety regulation.

Improper handling, storage and disposal of pesticides can result in direct worker and community exposure and environmental contamination (including of groundwater), with the consequences noted above.

C.4.4 POTENTIAL IMPACTS OF SUPPORT FOR TOOLS AND MECHANIZATION

Heavy agricultural machinery can damage the soil, leading to poorer crop yields and increased pollution from agricultural land. The adverse impacts of driving heavy machinery on agricultural fields can be soil compaction, characterized by increased density of the soil; reduced pore volume, which is important for storing air and water; and a reduced ability to drain surplus water.

Agricultural equipment engines also use oil and fuel that contribute to air and soil pollution. The diesel equipment and diesel fuel available in developing areas typically generates high levels of particulate matter or soot that contains carcinogenic compounds and toxic such as arsenic, selenium, cadmium, and zinc (Fugelsnes, 2011). Particulate emissions increase when equipment is poorly-maintained or excessively worn. In addition to particulates and other pollutants, fuel combustion also produces GHG emissions.

Heavy machinery and equipment can also pose risks to human health and safety. Negligence or defective farm equipment can cause serious and even fatal injuries.

Use of draft animals for plowing tends to have a lower risk of soil compaction and over-tillage than use of machinery. However, animal traction also tends to require higher farmer time and labor input, and the use of animals has impacts associated with livestock production, as discussed in the USAID Livestock SEG.

C.4.5 POTENTIAL IMPACTS OF SUPPORT FOR IRRIGATION

Irrigation presents a set of risks associated with construction of irrigation systems, water abstraction, conveyance, distribution, storing, and application. The risks may include impacts from poorly constructed irrigation systems; over-extraction of water; salination or permanent degradation of irrigated soils; and contamination of surface and groundwater with agro-chemical leaching and runoff. For further information on irrigation please see Annex 1.

C.4.6 POTENTIAL IMPACTS OF ENERGY USE

Energy use is a cross-cutting issue with multiple potential environmental and social impacts. Crop production intensification can help achieve global food security through use of high-yielding crop varieties, fertilizers, irrigation, and pesticides. However, intensification using these means requires significant energy inputs:

- Earlier in the value chain, significant energy is used in the manufacturing of fertilizers and chemicals produced off the farm.
- During crop production, energy is required as fuel or electricity to operate machinery and equipment (including irrigation systems), to heat or cool buildings, and for electrification.
- Later in the value chain, processing and transport are typically energy intensive.

Increasingly, supply and consumption of energy for intensification of agricultural production contributes to pollution, environmental deterioration, and GHG emissions. See Figure 11 below.

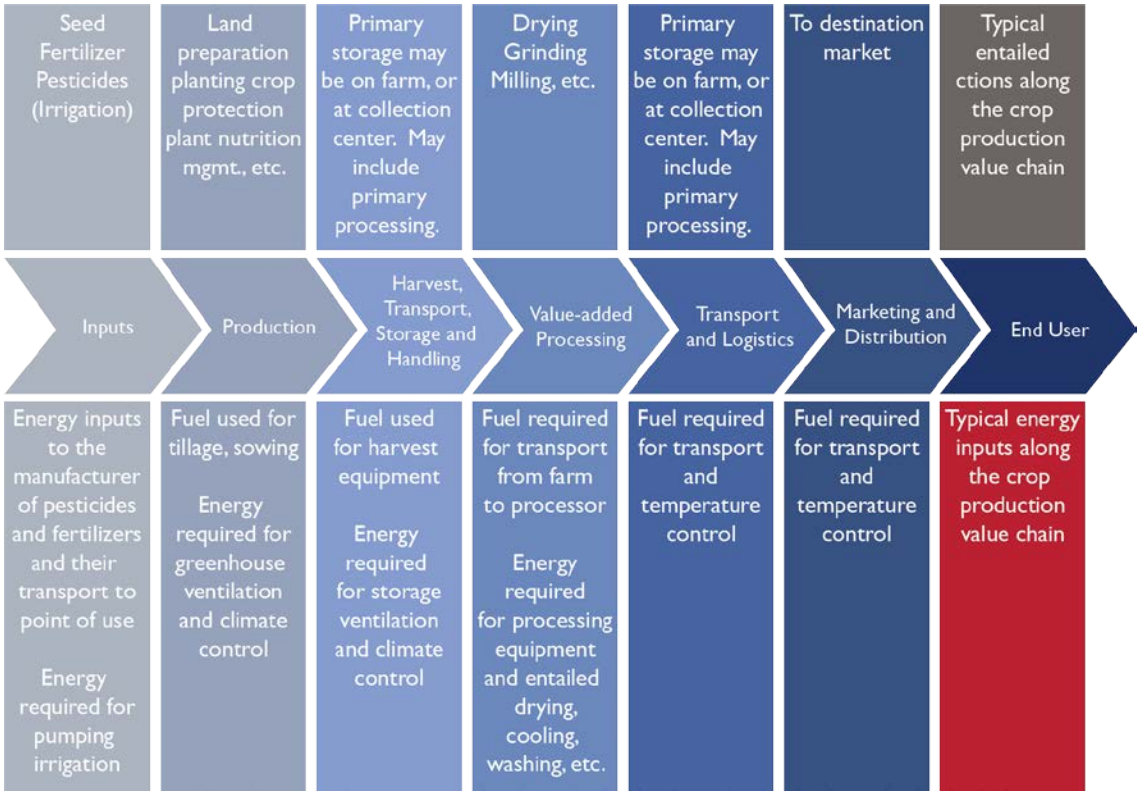


Figure 11. Energy use in agriculture

C.5 POTENTIAL IMPACT OF SUPPORT FOR CROP PRODUCTION INNOVATION/RESEARCH AND DEVELOPMENT (R&D)

Support to innovation/R&D can take a number of forms, and the potential environmental impacts vary accordingly. Some typical forms of R&D and their entailed potential impacts are:

- **Field and farmer surveys** to gather information regarding varieties being cultivated, pests, biological controls, land use, cultivation, and crop protection methods, and other information regarding crops, the crop production system, and its environmental and social context. Such information-gathering surveys that do not involve sampling and laboratory testing have negligible environmental impacts.
- **Surveys and research that requires sampling and laboratory experiments and analysis.** Impacts of sampling and laboratory research that do not require physical containment are principally laboratory occupational safety and health hazards – particularly exposure to hazardous chemical reagents and potentially to pathogens, depending on the nature of the samples. Improperly managed laboratory waste may pose a threat to people and to the environment. Additionally, if biological samples include endangered species or are conducted for the purpose of "gene prospecting", biological surveys and use of the resulting information may be subject to host country regulation and restrictions.
- **Containment facility research.** Containment facilities provide a combination of design features and procedures to prevent the release of organisms that are the subject of research into the environment. Containment facility research – generally involving new varieties (GE or

traditional) or crop pests and control methods – s undertaken because field release of the organisms involved is not proven to be safe. Potential risks may be those outlined below under GM/GE varieties or the risks of release of a plant pathogen or pest outside the facility. Accordingly, containment facility research requires specific risk assessment and strict protocols – see section D.

- **Development of GM/GE varieties.** These are crop varieties into which genetic material that confers new traits has been deliberately introduced by modern genetic techniques, or on which gene-editing techniques have been applied towards the same end. Generally, these will be smallholder-appropriate varieties with traits that address food security priorities—many with environmental co-benefits—such as improved nutritional content, climate resilience, drought resistance, and/or resistance to pests and diseases.

  However, they also present environmental and health risks that must be carefully considered, including the GE organism's safety for food and animal feed (including potential toxicity, pathogenicity, allergenicity, or nutritional changes) and safety for the environment including potential for weedy or invasive persistence, unintended gene flow to other organisms, or impact on non-target organisms. In all cases, the potential benefits and risks will vary depending on the specific crop and the engineered gene or trait. Enabling policies and local capacity to effectively regulate the proposed activity are also key considerations.

  These risks, along with social and political sensitivities regarding GE organisms in many countries, mean that field release (and often research involving) of GE organisms is subject to strict biosafety review procedures in most countries; see also containment facility research, immediately below. USAID actions involving GE organisms are also subject to USAID's Biosafety Review Procedures, set out in ADS 211.

- **Field trials of varieties, farming systems, cultivation and crop protection methods**. The path for taking a crop production innovation (an improved crop variety, a new crop protection product or technique, or a new cultivation practice) to adoption or commercialization almost always includes field trial and then demonstration plots. There are particular risks to ecosystems and/or existing genetic resources when field trials involve a crop, biological control, or other species new to the cultivation zone; addressing these risks is one important function of the earlier stages of the innovation process, well before the point of field trial. Assuming these risks are addressed, the limited scale of field trials mean that field trials *per se* rarely pose the broader set of environmental risks outlined in B.1. However, the risks presented by pesticide use and other occupational safety and health risks in any cropping operation still apply.

- **Efforts to scale and disseminate innovations** usually involve a mix of demonstration plots, extension services and input provision, and present the risks outlined in C.1., C.2.3, and C.4. These risks must be evaluated for the specific innovation being promoted. They must also be evaluated at the intended scale of full adoption, rather than the scale of the demonstration plots

***Note**: where adverse impacts are reasonably foreseeable, USAID-funded research and development activities are not eligible for the categorical exclusion otherwise available for "controlled experimentation" under the agency's environmental procedures.*

C.6 POTENTIAL IMPACT OF SUPPORT FOR MIXED CROPPING FARMING SYSTEMS AND AGROFORESTRY

In general, mixed cropping is seen as environmentally preferable to monocrop agriculture—assuming that all species involved are appropriate to the agro-ecological zone (see A.4.1), that agrochemical inputs are used safely and appropriately (see D.1.4 and D.1.6), and that GAPs (see A.4.9) are otherwise followed.

This said, mixed farming systems do entail the potential impacts addressed throughout this section. As with any other farming system, the potential impacts will vary with crops/species chosen, agro-ecological zone, cultivation practices used, and other key parameters of the system.

In addition, farmers in mixed systems must divide their attention and resources over several activities, thus leading to reduced economies of scale. Resource-poor farmers that use mixed farming need to apply labor- intensive techniques. Mixed systems involving livestock may require fencing, place increased pressure on water resources, and require careful management of the entailed manure.

See the USAID Forestry SEG for additional treatment of agroforestry, and the Livestock SEG for discussion of livestock impacts and their mitigation.

C.7 POTENTIAL IMPACT OF SUPPORT TO HARVEST, POST-HARVEST, LOGISTICS, STORAGE, MARKETING AND FOOD PROCESSING

Note*: MSMEs and Food Processing are addressed in the Food Processing Resource Efficient and Cleaner Production Briefing and Resource Guide, a part of the USAID SEG series.*

The harvest and post-harvest segments of the crop production value chain are critical to the safety and quality of crop-based food. They also present a set of environment and occupational health and safety risks. These risks vary according to the methods and technologies being used/supported, but may include all of the following:

Solid Waste Production. Processing can result in the generation of solid organic and inorganic wastes that must be handled properly. Additionally, spoiled products may need to be disposed of, in which case, the spoiled products could be hazardous for human or animal consumption (e.g., aflatoxin contamination). Discarded materials can contaminate groundwater.

Generation of Wastewater/Liquid Waste. Liquid wastes from processing can contain significant quantities of organic and inorganic matter. These wastes, if improperly disposed, can generate standing water that may become a breeding ground for disease vectors.

Wastewater/liquid wastes from processing can also pollute ground and surface waters, with impacts that depends on the quantity of wastewater relative to the receiving waters and the characteristics of both. In general, however, impacts of concern include changes to water pH and temperature, increased nitrogen and phosphorus load that lead to eutrophication, and long-term problems resulting from the discharge of organic compounds and heavy metals.

Water use. Excess abstraction of fresh water for processing may adversely affect other users and ecosystems.

Energy Consumption, GHG Emissions, and Air Pollution. All energy consumption has an impact on the environment, and processing, storing, and transporting agricultural produce requires significant energy—with food transportation quickly becoming one of the world's fastest growing sources of GHG emissions. In developing areas, equipment, such as pumps, chillers, motors, and engines are often low-efficiency and/or are poorly maintained, which increases energy use and emissions. Diesel generators in particular generate disproportionately high levels of GHG emissions and local air pollution.

Beyond emissions from energy use, air pollution can result from refrigeration equipment, which uses refrigerants that contribute to ozone depletion and from combustion or landfilling of waste materials. Some refrigerants may also be potent GHGs, contributing to climate change.

Consumer Health Risks. Actors along the harvest and post-harvest segments of the value chain -- particularly smallholders and MSMEs, may have limited availability of safety equipment and limited knowledge of required food-safety procedures. Poor manufacturing practices and absence of the necessary sanitation and food safety measures can lead to chemical and microbial contamination (Obadina, 2015). For example, poor storage conditions can result in aflatoxin-producing *Aspergillus* molds spreading within a storage facility; see A.4.9.

Note: the use of pesticides for protection of agricultural commodities in transport and storage or in food processing activities is addressed in C.4.3.

Noise Pollution and Odors. Food processing facilities may create noise pollution and odors; impacts may range from the nuisance level to significant physical and psychological health consequences for regularly exposed individuals and communities.

Occupational Health Hazards, Worker Health, and Safety. Farmworkers and post-harvest food processors are typically exposed to numerous safety, health, environmental, biological, and respiratory hazards, including heat exposure, falls, musculoskeletal injuries, hazardous equipment and machinery, unsanitary conditions, exposure to pesticides, and other risks. Hazards may include physical injury, respiratory injury, and exposure to toxic chemicals including pesticides.

Unlawful or Unfair Labor Practices. Enterprises may not provide equal employment opportunities for women and minorities and/or may utilize child labor.

Both occupational health and unfair labor practice risks are heightened when national occupational labor standards are poorly-developed or enforced.

C.8 POTENTIAL IMPACT OF CROP PRODUCTION ACTIONS INTEGRATED WITH NUTRITION, DISASTER RISK REDUCTION, MSME SUPPORT, AND NATURAL RESOURCE MANAGEMENT

C.8.1 POTENTIAL IMPACT OF CROP PRODUCTION ACTIONS IN SUPPORT OF NUTRITION IMPROVEMENT ACTIVITIES

Household agricultural production has direct and important linkages with household dietary patterns and nutrition. The main pathways through which expanded agricultural production can influence nutrition *at the farm-level* include:

- **Income from agriculture.** Increased household income from any activity, including agriculture, can alter the amount, composition, and quality of food consumed, and facilitate the purchase of health and nutrition-related goods and services. That said, commercialization of agriculture and the resulting shift away from staples to cash crops have not necessarily resulted in improvements in children's nutritional status and can, in fact, have negative nutritional consequences (FAO, n.d. (d)). Among other factors, awareness of good nutrition and its importance is important in translating income gains to improved nutritional status.
- **Consumption of own production**. The typical dependence of smallholders on a small number of cereal crops raises concerns about their diets being energy-rich but nutrient-deficient. Increased production can address caloric deficits—but may not address micronutrient and amino acid deficiencies unless production is diverse.
- **Biofortification.** Biofortification is the "process by which the nutritional quality of food crops is improved through agronomic practices, conventional plant breeding, or modern biotechnology" as opposed to traditional fortification in which nutrients are added during processing (WHO, n.d.).

  Farming practices that focus on soil health improve nutrition because soil quality affect the composition and health of plants. Growing crops with sufficient content of essential micronutrients improves nutritional quality of food supply and provides farming household with health benefits.

  Examples of biofortification include "iron-biofortification of rice, beans, sweet potato, cassava, and legumes; zinc-biofortification of wheat, rice, beans, sweet potato, and maize; provitamin A carotenoid-biofortification of sweet potato, rice, maize, and cassava; and, amino acid and protein-biofortification of sorghum and cassava" (WHO, n.d.).

  Biofortification may be particularly important in the context of climate change: new research indicates the possibility of a relationship between projected higher levels of atmospheric CO_2 and lower nutrient levels, including zinc, iron, and protein in grains (Scheer & Moss, n.d.).
- **Factors linked to gender.** Women's engagement and empowerment in communities , such as control over income and reduced workload, are positively associated with better maternal nutrition. These are not automatic outcomes and but must be integrated in crop production activities.

Thus, achieving nutritional benefits impacts from support to crop production is dependent on careful design, with attention to issues such as crop diversity, gender, nutritional education, and farming practices. Absent this, nutritional benefits may be minor, and adverse effects on nutrition are possible if households' production becomes less diverse or economic benefits accrue narrowly to men.

Note: for biofortification research, including use of GE crops, see section C.5.

C.8.2 POTENTIAL IMPACT OF CROP PRODUCTION ACTIONS INTEGRATED WITH DISASTER RISK REDUCTION

Disaster risk reduction (DRR) in the crop production context means adopting crops, cropping systems, and practices that increase the resilience of the crop production system to natural hazards. Many crop production DRR practices—such as use of drought and/or flood-tolerant varieties, mulching and other water conservation measures, and use of compost—have environmental co-benefits such as improved soil health, reduced pollution, and increased carbon sequestration (FAO 2017c).

This said, the promotion of any crop or farming system can have adverse impacts, as elaborated throughout this section C. Avoiding such impacts requires that crops/varieties and practices promoted are proven *in practice* to be appropriate to the agro-ecological zone (see A.4.1) and farmer capabilities.

Note: Emergency seed/seed security aid is addressed in Section C.4.1.

Figure 12. USAID supports Zambia in strengthening its public health system at the national, provincial, and community levels. Photo: John Healy for USAID

C.8.3 POTENTIAL IMPACT OF MICRO, SMALL AND MEDIUM ENTERPRISES (MSMEs) SUPPORT INTEGRATED INTO CROP PRODUCTION ACTIVITIES

The potential impacts of support to MSMEs in any given segment of the crop production value chain is no different from the impacts of other types of support to the segment in question. As such, these impacts are covered elsewhere in this section: for the impacts of support to harvesting, post-harvesting, logistics, storage marketing and food processing activities, see section C.7. For the impacts of support to input supply enterprises, section C.4.

Given their small scale, the impact of a given MSME may be minor. However, without assistance, MSMEs often have low awareness of and capacity for the implementation of environmentally sound practices. Therefore, cumulative impacts of MSMEs across a given value chain segment can be significant.

C.8.4 POTENTIAL IMPACT OF CROP PRODUCTION ACTIVITIES INTEGRATED WITH NATURAL RESOURCES MANAGEMENT (NRM)

Integration of crop production activities into NRM programming is undertaken to best achieve specific conservation goals. For example, the goal of better-preserving critical ecosystems and ecosystem services may be addressed by supporting crops and cropping systems that better maintain key features of the subject ecosystems and the landscape while also offering acceptable economic returns.

Despite a conservation goal, adverse environmental and social impacts are possible, just as they are with support for any crop and cropping system. These potential impacts are addressed throughout this Section C.

Further, because this type of programming integration is most likely to occur in the context of protected areas and critical landscapes and ecosystems, these impacts may be more significant than they would be otherwise. To understand and address these potential impacts, an environmental review is usually required that examines the specific environmental context of the intervention and the specific practices and crops to be promoted.

C.9 CONSIDERATION OF SOCIAL IMPACTS IN CROP PRODUCTION

Note*: Occupational safety and health issues and labor practices are integrated into the previous sections and not addressed separately here.*

C.9.1 POTENTIAL ADVERSE IMPACTS ON WOMEN AND VULNERABLE GROUPS

Crop production activities can create or exacerbate wide disparities for women and other marginalized community members' access to and control over productive resources, service delivery, and market opportunities (Chapados et al., 2012).

Crop production interventions may increase the economic incentive that smallholder households and farming communities take children—particularly girls—out of school to provide farm labor.

According to the International Labor Organization (ILO), in farming, women and children are often responsible for operating machinery, using sharp tools, and spraying chemicals, and they are more often more likely to experience amputations, cuts and burns, pesticide poisoning, and other adverse health impacts.

C.9.2 POTENTIAL ADVERSE IMPACTS ON CULTURAL SITES

Crop production activities may directly destroy or disturb sites of historic, religious/sacred, or other cultural significance. Impacts on cultural sites may also be indirect, such as when crop production activities stimulate land conversion or repurposing away from a project intervention site.

C.9.3 POTENTIAL IMPACTS OF INSECURE LAND TENURE

Land tenure security refers to the effective level of protection that individuals and groups have against eviction and/or being barred from economic use of land to which they have a legal or customary right.

Crop production activities can create an economic incentive to convert land to alternate, higher-value uses (e.g. for cultivation of a cash crop). Particularly when land tenure is insecure, this can result in landowners converting land farmed by tenant smallholders to commercial farming use, or in smallholders being otherwise dispossessed of their land. Or, it may result in land conversion, so that households and communities lose access to the land—and with that access, the ability to gather fuelwood, graze animals, harvest non-timber forest products, and/or engage in other uses of the land that are important to food security and/or livelihood.

Insecure land tenure also means that farming systems and practices that focus on sustaining land productivity over the long-term, or which require time to deliver benefits (e.g. agroforestry) will frequently find little acceptance, as farmers have no assurance that they will benefit from their investments of money and labor.

C.9.4 SOCIAL IMPACTS FROM LOSS OF ECOSYSTEM SERVICES AND APPROPRIATION OF NATURAL RESOURCES

As noted in the sections above, land conversion for crop production may mean that households and communities lose the ability to gather fuelwood, graze animals, harvest non-timber forest products, and/or engage in other uses of the land that are important to food security and/or livelihood. These are examples of the loss of ecosystem (provisioning) services provided by the land. Other ecosystem services that may be lost due to land conversion include, inter alia, flood control, purification of surface waters, groundwater recharge, and local climate moderation. Loss of these ecosystem services may result, in turn, in impacts to human livelihood and well-being.

Land conversion may also result in increased abstraction of water for agriculture, adversely affecting other users and adversely affecting ecosystem services provided downstream.

Social impacts resulting from loss of ecosystem services and appropriation of natural resources may, in turn, fuel land-use conflicts. Examples include conflict between smallholders/communities and commercial farmers and between pastoralists and agriculturalists, among many others.

Agricultural intensification may also result in increased abstraction of water, and loss of ecosystem services provided by a landscape that was previously less intensively cultivated.

Box 3. Ecosystem Services

Ecosystem services are the benefits people and society derive from properly functioning ecosystems. Consistent with the influential Millennium Ecosystem Assessment framework (MEA, 2005) and The Economics of Ecosystems and Biodiversity (TEEB) Framework (Sukhev et al, 2010) the USAID Biodiversity Policy (2014) names four categories of ecosystem goods and services: 1) provisioning goods or services; 2) regulating services; 3) cultural services that provide spiritual, aesthetic and recreational benefits; and 4) supporting services necessary for the production of all other ecosystem services.

Table 2 below presents the ecosystem services inventory used by the MEA and TEEB, respectively. See also USAID's Environmental Compliance Factsheet: Ecosystem Services in Environmental Impact Assessment.

TABLE 2. ECOSYSTEM SERVICES INVENTORY USED BY THE MEA AND TEEB		
TYPE OF SERVICE	MEA (2005)	TEEB SYNTHESIS REPORT (2010)
Provisioning	Food Fiber Fresh water Biochemicals, natural, medicines, pharmaceuticals Genetic Resources	Food Raw materials Fresh water Medicinal Resources
Regulating	Climate regulation Air quality regulation Natural hazard regulation Water purification and waste treatment Erosion regulation Pollination Disease Regulation Pest regulation Water regulation	Local climate Carbon sequestration and storage Air quality regulation Moderation of extreme events Waste-water treatment Erosion prevention and maintenance of soil fertility Pollination Biological control
Supporting	Nutrient cycling Soil formation Primary production	Habitats for species Maintenance of genetic diversity
Cultural	Recreation and ecotourism Aesthetic values Spiritual and religious values	Recreation and mental and physical health Tourism Aesthetic appreciation and inspiration for culture, art and design Spiritual experience and sense of place

Source: (SCBD and UNEP-WCMS, 2012)

D. MITIGATION RECOMMENDATIONS, INCLUDING DESIGN MEASURES

Mitigation is the implementation of measures to:

- Prevent, reduce, or offset the adverse environmental and/or social impacts of a proposed action on the environment, human health and welfare.

- Reduce the emission of GHGs that would result from a proposed action or enhance sinks of GHGs associated with that action.

This section presents mitigation options and approaches that may be used to address the impacts presented in Section C and is organized in parallel to section C.

This section does not address monitoring. In general, mitigations must be monitored to assure that they are (1) implemented and (2) sufficient and effective. The design of monitoring, including indicators, methodology, frequency, and responsible parties is part of the process of developing environmental mitigation and monitoring plans (EMMPs, also called environmental and social management plans (ESMPs)). EMMPs provide the specific management framework for implementing mitigation measures; see www.usaid.gov/environmental-procedures/environmental-compliance-esdm-program-cycle/mitigation-monitoring-reporting.

The choice of appropriate mitigation and its detailed design is highly context-dependent. This section provides some guidance regarding selection of appropriate mitigation but cannot anticipate all situations nor substitute for knowledge of local context.

D.1 MITIGATING ADVERSE IMPACTS OF CROP PRODUCTION ON THE ENVIRONMENT

This section presents mitigation measures to address the adverse impacts of agricultural crop production described in Section C.1. It is organized as follows:

1. Preserving land and landscapes (D.1.1)
2. Preserving biodiversity (D.1.2)
3. Controlling pollution (D.1.3)
4. Managing soil nutrition and soil conservation (D.1.4)
5. Water management and water conservation (D.1.5)
6. Safer pesticide use, including integrated pest management (D.1.6)
7. Implementing more sustainable agronomic practices (D.1.7)
8. Introducing and promoting greenhouse and urban agriculture (D.1.8)
9. Applying more sustainable agricultural practices to specific crops (D.1.9)

An important cross-cutting aspect that is not addressed in any one section is the importance of building awareness of the need for environmental stewardship to sustain the long-term productivity of land and ecosystem services such as clean air and water. Without this awareness and environmental sensibility, environmentally sound practices are difficult to motivate and sustain.

D.1.1 PRESERVING LAND AND LANDSCAPES

Land conversion, erosion, and poor agricultural practices are three principal threats posed by crop production to land and landscapes (see C.1 and A.4.3–5). This section presents mitigation measures to address these threats. A basic understanding of soil erosion is essential background to this section; see box directly below.

BOX 4. EROSION AND EROSION RISK

Some soil erosion and/or displacement accompanies any agricultural practice. The physical parameters of the climate and the land's slope, soil depth, and soil type all affect the potential for runoff and the actual rate of erosion.

Surface cover is a major factor in controlling erosion because it reduces the impact of raindrops falling on bare soils and wind removing soil particles. It also reduces the speed of water flowing over the land.

Erosion risk is significantly reduced when there is more than 30 percent soil cover. Tree roots help prevent landslides on steep slopes and stream bank erosion but they do not prevent erosion on moderate slopes.

Thus, depending on the characteristics of the land, it may not be suitable for agriculture, or suitable only for a production activity which limits erosion.

The risk of soil erosion may be quantified through models like the Universal Soil Loss Equation, the Water Erosion Prediction Project model (WEPP), and the European Soil Erosion Model. These models use formulas to determine potential soil loss in terms of tons per hectare per year, based on rainfall, soil erodibility, topography, crop practices, and conservation efforts. Models may be valuable in monitoring soil and water conservation efforts, which are typically gradual improvements and incremental reductions in the erosion rate over time. Their formulas, however, require data (such as rainfall intensity or soil erosivity) that may be difficult for small projects to obtain.

Minimize Agricultural Land Expansion by Intensifying Production using inputs and improved techniques to increase productivity and reduce losses per unit of land, therefore reducing the pressures for land conversion.

However, use of these inputs and techniques may themselves have adverse impacts as described in Section C, and these impacts must be identified and mitigated (see especially D.4) if intensification is to be environmentally sound (see also "sustainable intensification" in A.3).

Promote Alternative Livelihoods. Support for livelihoods other than crop production can reduce pressure for land conversion, particularly in marginal areas where cultivation easily leads to erosion and soil degradation. Examples of such alternative livelihoods include value-adding businesses based in non-traditional agriculture or non-timber forest products.

However, alternative livelihoods may themselves have adverse impacts that must be identified and mitigated.

For additional information, see [GFSS Technical Guidance: Objective 2, Strengthening Resilience Among People and Systems; Diversifying Livelihood Risk In and Beyond Agriculture](#).

Maintain Appropriate Riparian Buffers. Maintenance of riparian buffers (see box below) is extremely important both to control streambank erosion and to reduce surface water pollution.

The appropriate width of a riparian buffer zone depends on the topography, vegetation, wildlife, and ecosystem services supported by a body of water. However, 30m is a typical minimum for a small stream, with Zone 1 being about 5m, Zone 2 about10-15m, and Zone 3 about 10-15m. (See box for definition of zones). When the riparian zone is on a steep slope (>15 percent), the minimum width of Zone 3 should be doubled (Sweeney & Newbold, 2014).

It is strongly recommended that buffer zones be wider than this minimum, especially in flood-prone zones. Some areas may require buffer zones of 150m or greater if the land encompasses extensive wetlands, has wildlife migration corridors, is meant to sufficiently remove metals and non-fertilizer pollution, or needs protection from possible salinization.

Figure 13. Gordon Mumbo, team leader of the Sustainable Water for the Mara Activity. Photo credit USAID

BOX 5. RIPARIAN BUFFERS: 3 ZONES

In general, riparian buffers are divided into three zones:

- **Zone 1** is the area adjacent to the body of water, designated to ensure bank stability and natural riparian ecology (*no harvesting, domesticated animal grazing or rearing, or resource extraction should occur here*);
- **Zone 2** is the area further from the body of water but adjacent to Zone 1, with trees, shrubs, and other vegetation that uptake nutrients and pollutants while providing a habitat for wildlife (*no domesticated animals should be in this area, but sustainable tree and non-timber forest harvesting can occur here along with the scattering of removed woody vegetation*); and
- **Zone 3** is a further in-land area in between Zone 2 and the designated farmland that consists of tall grasses or thick vegetation that filters runoff, prevents erosion, and provides space for wildlife movements.

In general, a diverse combination of plant species across these zones that meet native wildlife and pollinator needs would be appropriate and likely aid in the preservation of natural areas, ecosystem services, and riparian zones (NRCS, 2010a).

Classify Land Capability and Use Land in Conformity with its Capability. Land capability classifications identify appropriate land uses based on parameters such as slope, soil depth and soil quality. Using land in conformity with its capability is essential to sustainable management of the landscape, and particularly to erosion control. A simple land capability classification scheme is provided below:

TABLE 3. LAND CAPABILITY CLASSIFICATION SCHEME SUGGESTED FOR SMALL FARMERS IN THE TROPICS

SLOPE CLASS	SLOPE (%)	SOIL DEPTH (cm)	LAND CAPABILITY*	MAJOR CONSERVATION TREATMENT	APPLICABLE TOOLS	LAND USE
1	0–12	>15	C1	Mainly agronomic conservation measures; simple terraces on slopes approaching 12%	Large machine or hand	Any crop
		<15	P	Grass cover	—	Pasture
2	12–27	>30	C2	Bench terraces & simple terraces	Medium-sized machine or hand	Any crop
		<30	P	Hillside ditches	—	Pasture
3	27–36	>45	C3	Bench terraces & simple terraces	Hand or small machine	Any crops
		<45	P	Hillside ditches, zero grazing	—	Pasture

4	36–47	>55	C4	Simple terraces & benches	Hand or walking tractor	Annual & perennial crops
		<55	P	Hillside ditches, zero grazing	—	Pasture
5	47–58	>60	FT	Orchard terraces	Hand	Tree crop
		<60	F or AF	Forest cover or agroforestry	Hand	Trees or tree crop
6	>58	All depths	F	Forest cover	—	Forest only

*C = cultivatable land; P = pasture; FT = land for food, fruit and tree crops; F = forest land; and AF = agroforestry.

Source: (Sheng, 1989), available at https://www.qld.gov.au/environment/land/vegetation/soil/erosion/management.

Implement Water-born Erosion Control Practices. As indicated by the table above (see the "major conservation treatment" column), land capability classifications assume that appropriate erosion control measures are implemented on slopes. Major conservation measures to prevent erosion in hilly areas include terracing; using bund and retaining walls; planting on the contour, practicing conservation tillage, maintaining grass cover, and planting in critical areas (see D.1.7); creating diversions (see D.1.5); maintaining forest cover; and using lighter tools and machinery.

> ***Note: Terraces*** *must be correctly designed, constructed and maintained; significant adverse impacts on the landscape may result from failed terraces. Terracing requires careful long-term planning in which political and social stability plays a vital role (Duprez, 2016).* ***Diversions*** *also must be correctly designed, constructed and maintained, and require engineering oversight. See D.1.5. See also discussion of considerations regarding conservation tillage in D.1.7.*

Implement Wind-born Erosion Control Practices. Protecting soil from wind erosion is best done by keeping the wind off the soil surface by maintaining a covered soil surface, either with growing vegetation or with crop residues. Growing vegetation, either crops or cover crops, protects the soil by keeping winds higher off the soil surface.

Reducing tillage and maintaining standing crop residues on the soil surface between growing crops also reduces soil loss from wind erosion. Use of a mulch on the soil surface can protect from wind erosion. Maintaining a bare soil at higher moisture content with irrigation can also reduce wind soil erosion.

Reducing the distance the wind blows across the soil surface can reduce the force of the wind and the ability to move soil particles, and can be accomplished by reducing field width, strip cropping, or planting windbreaks (usually several rows of trees and shrubs) in the landscape.

Improve Land Use Planning at the community level with a focus on matching land capability to land use and maintenance of long-term productivity. This supports all of the mitigation measures discussed above and is likely to improve crop production and food security and enhance the livelihoods of small and marginal farmers (Rao et al., 2015).

Address Insecure Land Tenure. When tenure is insecure, producers will often not be willing to engage in practices that support long-term fertility and productivity, unless these practices can also be justified purely on the basis of short-term returns—which is often not the case. Like improved land-use planning, strengthening tenure supports all of the above-listed mitigations.

Support Shifting Cultivation Only in Sustainably Managed Forests/Landscapes. Shifting cultivation agriculture can result in land that may only be fertile for a few years before nutrients are depleted and new land must be cleared. This agricultural method can be unsustainable if the frequency and scale is not appropriate for the system, which often occurs with rapidly growing populations trying to meet food needs. Shifting cultivation can then contribute to habitat and species loss, increased air pollution, and the spread of wildfires.

Sustainably managed forested areas are capable of self-renewal after a disturbance, and do not require human intervention to regenerate. Degraded forested areas cannot regenerate on their own and require human intervention to regenerate. Human interventions, if even pursued, will likely take decades to be successful.

Support Land Clearing Only with Detailed Assessment and Thorough Mitigation. Land clearing –i.e. removing trees and other vegetation from a site – may also include grubbing, which is the excavation of stumps and roots. Grubbing can destabilize critical areas, which includes steep slopes, areas where it is difficult to establish vegetation (such as under heavy canopy), or areas that experience concentrated water flows.

Land clearing is environmentally sound only when the ecosystem services provided by the land are maintained (or immediately restored). This requires detailed environmental assessment to support site selection (for example, wetlands, riparian areas, and fish and wildlife habitats must be at most, minimally disturbed (USDA, 2016)) and identify mitigation measures. These may include:

- Identifying and preserving healthy trees, vegetation, and wildlife habitats;
- Ensuring maintenance of all riparian buffers; and
- Preventing soil erosion and sedimentation through revegetation of denuded areas with cover appropriate for a given landscape and soil type.

Land clearing usually requires management of the resulting debris. Where possible, the volume of stumps, roots, logs, brush, limbs, tops, and other debris resulting from clearing or thinning operations should be reduced by processing (i.e., cutting up or breaking down) the material. When material cannot be processed, the organic debris in the woody portion of a riparian zone (not in the flow path of a floodplain) should be dispersed so as to create habitat and nutrient sources, while being careful not to destroy, degrade, or impede healthy vegetation or habitat conditions.

D 1.2 PRESERVING BIODIVERSITY

Conserve Land to Preserve Biodiversity. Wildlife and vegetation depend on natural areas for food, shelter, and reproduction. Thus, as land and landscapes are preserved, as described above, a key environmental benefit is the protection of unique habitats and regional biodiversity.

Promote Alternatives to Monocropping. Farming approaches such as agroforestry (see D.6 and the Forestry SEG), and polycropping (see D.1.7) are alternatives to monocropping that better mimic natural ecosystems and can produce more food, and potentially more income, using fewer resources. However, these systems also have potential impacts that must be considered and mitigated.

Prevent Introduction of Invasive Species. No new organisms of any kind should be introduced into any ecosystem without proper studies and host country approval. Non-indigenous pests, weeds, plants, insects, fungi, bacteria, viruses, and other agents can severely interrupt the production of crops and spread disease.

Some invasive species have been intentionally introduced to an ecosystem, with their potential negative effects misjudged or under-estimated. For example, intentional introduction of new natural enemy species to suppress populations of invasive pests has long been an important part of biological control. Introduced natural enemies have included invertebrates, vertebrates, and microbes, and these have been employed against pest plants, arthropods, and vertebrates. While these natural enemies sometimes have success against invasive species, exotic natural enemies can also act as invasive species in their own right (MB & AM, 2017). In general, use of local species for biological pest control is preferable wherever possible.

Replanting and Introducing Local Species. Many desirable and ecologically important species can be difficult or very time consuming to propagate by seed. Establishing, promoting, or supporting nurseries involved in vegetative propagation can help promote local species (Luna, 2009). However, the impacts of nurseries must be managed appropriately.

D 1.3 CONTROLLING POLLUTION

As described in C.1, Crop production can result in air, water, and soil pollution:

- Water pollution includes siltation of surface waters from erosion of topsoil carried by runoff into surface waters. It also includes nutrient, pesticide, pathogen (e.g. from livestock slurries and manures spread on fields) and potentially fuel and oil pollution carried by runoff to surface waters or via leaching to groundwater. Water pollution that results from agricultural practices across a given landscape is called "non-point pollution".
- Air pollution includes emissions from fossil fuel combustion, burning of fields, windblown dust, and spray drift.
- Soils may be polluted by fertilizers, pesticides, fuels, and livestock slurries and manures.

Note: *Pollution from other segments of the crop production value chain is addressed in other parts of this Section D. Managing pollution from agricultural use of fossil fuels is addressed in D.4.4.*

Implement Erosion/Runoff Control Measures and Riparian Buffers. In reducing erosion, the erosion control measures described in D.1.1—including riparian buffers, using land to capability, and specific conservation measures—also reduce sedimentation and siltation of surface waters. This reduces transport to surface waters of nutrients and pesticide residues that are in soil. Riparian buffers also serve as a filter for excess nutrients and residues otherwise carried to surface waters by surface runoff and by subsurface flows. Erosion control measures, along with other practices described in D.1.7 also reduce surface water runoff, and thus, the transport of pesticides and fertilizers dissolved in runoff.

To have a meaningful effect on reducing sedimentation, siltation, and nutrient or pesticide pollution of waters at the catchment level, erosion/runoff control measures must be coordinated across the catchment.

Control Leaching. Leaching is the movement of contaminants, primarily water-soluble pesticides or fertilizers, carried by water through permeable soils. Site characteristics and soil types impact leaching. The control of fertilizer and pesticide pollution is addressed in Section D.4.

Managing Pollution from Irrigation and Drainage. Irrigated agriculture consumes water; the return flow (drainage) is more saline than the inflow and can be contaminated with fertilizer and/or pesticides. Different types of irrigation will have different impacts that require matching mitigation measures. In general, these measures include:

- Improving irrigation and drainage operations to match demand for irrigated amounts and timing;
- Managing irrigation and drainage to prevent spread of disease;
- Monitoring and enforcing water quality standards;
- Defining and enforcing water abstraction; and
- Defining and enforcing ecological requirements (Dougherty & Hall, 1995).

For further information about irrigation impacts and mitigation, see Annex 1: Irrigation.

Note: *Environmental management and mitigation for large irrigation schemes is usually specified via a full-scale environmental impact assessment (for USAID activities, a 22 CFR 216 Environmental Assessment).*

Control Volatilization and Drifts. Volatilization of pesticides and spray drift results in the deposition of agricultural contaminants that can pollute water and soil—see C.4.3. The control of pesticide pollution is addressed in Section D.4.

Promote Alternatives to Burning Crop Residue and Farm Waste. Burning crop residue is a pest control and field preparation measure that contributes to air, water, and soil pollution both locally and on a regional scale. This disposal method also adversely affects the nutrient budget within soils and is a major contributor to GHG emissions from agriculture.

Depending on the type of waste, alternative uses for crop waste can be beneficial for the environment. For example, rice stubble treated with urea can be used as a fodder for animals, or in biothermal energy production, paper manufacturing, mushroom cultivation, or bedding for animals (Kumar & Joshi, 2013).

Reduce GHG emission intensity. The following are all important ways to control and improve emission intensities from crop production (Russell, 2014):

- Improving fertilizer management and increasing use of compost, manure, and crop residue rather than synthetic fertilizer to provide nutrients to soil;
- Practicing conservation tillage;
- Preventing deforestation and practicing reforestation;
- Restoring degraded lands and cultivated soils into productivity;
- Reducing food losses and waste through better post-harvest practices, storage and processing;
- Maintaining power equipment and engines and purchasing higher-efficiency equipment; and
- Using wind or solar energy for pumping and drying.

D 1.4 MANAGING SOIL FERTILITY AND SOIL CONSERVATION

Sustained crop production without appropriate management in almost all cases will have adverse impacts on soil fertility—depleting (mining) soil nutrient reserves and/or degrading the soil physically and chemically (IAEA, n.d.; also see A.4.4 and C.1.1.) These impacts must be mitigated to sustain long-term productivity. More usually, this is framed and understood as soil fertility management being a necessary part of crop production and farm management.

Characterize Soils and Practice Integrated Soil Fertility Management (ISFM). Managing and conserving soil begins with characterizing soil including primary (N, P, K) nutrient levels, structure, depth, pH, salinity, and other factors mentioned throughout this section. Ideally, nutrient content of manures and composts are also assessed and known.

With this information in hand, the measures set out in this section should be promoted and undertaken in an integrated way under the principles of ISFM, ideally informed by a nutrient management budget – i.e. an accounting of all the nutrient inputs (e.g. fertilizers, rainfall, irrigation water, crop residue, compost) to a farm, as well as those being taken from the land (e.g. agricultural products, nitrate leaching, volatilization, phosphate runoff).

ISFM is the utilization of a set of agricultural practices adapted to local conditions to maximize the efficient use of nutrients and water and to improve agricultural productivity (see also A.4.4). ISFM strategies center on the combined use of mineral fertilizers and locally available soil amendments (see below). This improves both soil quality and the efficiency of fertilizers and other agro-inputs. In addition, ISFM promotes improved germplasm, agroforestry, and the use of crop rotation and/or intercropping with legumes.

Prevent and Manage Soil Waterlogging. Waterlogging occurs when there is too much water in a plant's root zone, which decreases the oxygen available to roots. Waterlogging can be a major constraint to plant growth and production and, under certain conditions, will cause plant death. This level of damage may not be apparent until the whole soil profile is saturated and water appears on the surface.

Heavy rains and flooding may cause waterlogging, as well as over-irrigation and/or inadequate drainage. Deteriorated soil structure often exacerbates waterlogging. Mitigation includes:

- Proper installation and maintenance of surface drainage
- Proper installation and maintenance of sub-surface or tile drainage—this is especially important in irrigated systems (see Annex 1: Irrigation)
- Utilization of raised beds, particularly where sediments and nutrients may enter waterways and threaten water quality
- Avoidance pf excessive irrigation, particularly in poorly drained soils (AS Miner Geotechnical, 2013). See Annex 1: Irrigation.

Prevent and Reduce Soil Compaction. Soil structure is essential for growing crops. It determines the soil's ability to hold water, nutrients, and air, and the soil's capacity for infiltration of elements necessary for root activity. Therefore, it is important to incorporate practices such as reducing tillage; minimizing physical trampling, particularly when the field is wet; and, when necessary, subsoiling to eliminate compaction (Scott, 2015). (See A.4.3 for impacts of tillage on soil structure.)

Amend Soil as Indicated Based on Properties. A soil amendment is a material added to a soil (i.e. physically incorporated into the soil, usually into the top 15-20cm) to improve its physical properties. Physical properties include water retention, permeability, water infiltration, drainage, aeration, temperature, and structure. The primary goal is to provide a better environment for roots (Davis & Whiting, 2013). Fertilizers, by contrast, provide nutrients in concentrated form for plant feeding.

Soil amendments can include:

- Organic fibrous amendments such as crop residue, green manure, and wood chips;
- Organic humus amendments such as compost and aged manure; and
- Inorganic amendments such as lime, sand, and clay.

In addition to improving soil physical properties, organic amendments can provide nutrients as they decompose. Nutrients provided in this way have low potential for nonpoint source pollution, as opposed to surface application of fertilizers. However, breakdown of organic amendments can also mine nutrients, particularly nitrogen, from the soil and affect soil pH. Livestock manures may have high salt content, and unless properly aged, contain pathogens—see below.

Thus, organic soil amendments, like fertilizers (D.4.2), should be used as part of an integrated soil fertility management approach.

Use Fertilizers Safely. See D.4.2.

Undertake Manuring and Composting. Spreading manure or compost over the soil conserves soil moisture and provides valuable nutrients to the soil through processes of decomposition. However, timing of manure application to agricultural soils remains a contentious topic in nutrient management planning, particularly regarding impacts on nutrient loss in runoff and downstream water quality (Liu et al., 2017). As noted, manures must be properly aged, or they may contaminate crops and surface waters with pathogens.

Composting is a fundamental practice of conservation and organic agriculture. Adding earthworms to compost (called vermicomposting) contributes additional benefits to traditional methods of composting, including suppressing plant disease. (Manure and compost may also be used as soil amendments, see above).

Green Manuring is the growing of plant materials with the sole purpose of contributing improved organic matter and nutrients to the soil. The improved soil quality in turn improves water retention capacity.

Mulch when Appropriate. Mulching is placing a layer of organic or inorganic material on the surface of the soil and over the root zone of the plants. Examples of mulch materials include straw, wood chips, and peat. Inorganic mulch, in the form of plastic sheeting, can also be used. Mulch is recommended for low to medium rainfall areas and is less suited for areas with very wet conditions. Its purpose is to reduce evaporation and runoff, inhibit weed growth, and moderate soil temperature. Organic mulch may be incorporated into the soil as an amendment after it has decomposed. However, mulching may not be suitable in all locations because planting of a new crop cycle through mulch or other crop residues may be difficult for nonmechanized agriculture. Plastic mulch can be effective in some situations but advanced technology and technical expertise may be needed to properly lay the plastic to make harvesting effective.

Identify and Manage Soil Salinity, Acidity, Alkalinity, Specific Ion Toxicity, and Sodicity. Each of these conditions has adverse impacts on crops production, but they differ in their cause and their impact (see Table 2).

TABLE 4. DIAGNOSING HIGH PH, SALINITY OR SODICITY PROBLEMS.

PROBLEM	POTENTIAL SYMPTOMS
Acidic (low pH) soil	wilting leaves, stunted growth, blighted leaf tips, yellowing of foliage or other leaf discoloration and poor stem development.
Alkaline (high pH) soil	Nutrient deficiencies manifesting as: stunted, yellow plants. Dark green to purplish plants.
Saline soil (excess salt in the soil)	White crust on soil surface. Water stressed plants. Leaf tip burn. Poor growth
Sodic soil (Soil with excessive sodium.)	Poor drainage. Black powdery residue on soil surface.
Saline-sodic soil (soil that is both saline and sodic)	Generally, same symptoms as saline soil.

Source: http://extension.colostate.edu/topic-areas/agriculture/diagnosing-saline-and-sodic-soil-problems-0-521/

Alkali soil reclamation generally involves the application and incorporation of gypsum into the soil followed by leaching. Fertilizers and chelates can be added to soils to increase concentrations of plant nutrients. Elemental sulfur, iron, and aluminum compounds can be added to soil as they cause the release of hydrogen when they react with water. Sulfuric acid may also be added directly. Additions of appreciable amounts of organic matter will help to acidify the soil as microbes decompose the material, releasing CO_2, which then forms carbonic acid. Many plants can tolerate pH values between 7 and 8, and some actually thrive at these higher pH values. Utilizing plants that grow well in mildly alkaline soils can be a method of mitigation and is therefore encouraged (Extension, 2015a).

Soil acidity amelioration. Soil acidity can be ameliorated and the pH of the soil increased by the addition of lime/limestone (calcium carbonate) and similar compounds that have been finely ground for use. Each lime-like amendment has its benefits and drawbacks, such as effectiveness, price, and purity (Extension, 2015b).

Salinity reclamation. Avoiding waterlogging and the use of saline irrigation water can reduce salt concentrations near roots, reduce crusting, and improve permeability and soil structure. Most reclamation approaches to treating saline soils involve leaching (flushing) of the soil with clean/relatively pure water. Sufficient water must be applied to dissolve the excess salts that have accumulated and cause them to percolate/flow out of the soil profile, particularly the root zone. To accomplish the leaching of salts, adequate drainage is requisite. Runoff should be avoided to prevent erosion. Other measures include using deep-rooted perennial crops and revegetation of saline seepage areas with plant species capable of taking up excess salt.

Sodicity reclamation. Soil sodicity is related to salinity and these two have common characteristics. However, they may need to be managed differently. Soils having both(salinity as well sodicity problems are saline-sodic soils and have the characteristics of both. Reclamation of sodic soils is generally done by application and incorporation of gypsum into the *soil* followed by leaching with water.

Addressing specific ion toxicity. High levels of boron, chloride, and sodium in irrigation water are potentially harmful to plants. Many trace elements, in addition to sodium, chloride and boron, are toxic to plants at very low concentrations, but these are rarely found at high concentrations. Ayers (1994) explains, "The most effective method to prevent occurrence of a toxicity problem is to choose an irrigation water that has no potential to develop a toxicity. But if such water is not available, there are often management options than can be adopted to reduce toxicity and improve yields."

D.1.5 WATER MANAGEMENT AND WATER CONSERVATION

Overdraw of surface or groundwater and adverse soil impacts of over-irrigation are typical adverse impacts of crop production.

Conserve Soil Moisture. Conserving soil moisture reduces water and irrigation needs. There are a variety of methods that can be used to conserve soil moisture. Most are relatively low cost, relying on locally available materials and technical capacity. Some methods function by providing cover for the soil to minimize direct heat and sun, others by slowing runoff and otherwise facilitating absorption of rain.

Soil moisture conservation methods include: conservation tillage, deep tillage, crop rotation, mixed cropping and interplanting, mulching, manuring and green manuring, contour plowing, and strip cropping (CTCN, n.d.). All are addressed in other parts of this Section D.

Most of these methods also are used for soil fertility management and conservation.

Harvest Rainwater to Reduce Draw on Surface and Groundwater. A rainwater harvesting system consists of a method to collect, divert, store, filter, and distribute water. Storing rainwater can be especially beneficial in arid climates, areas lacking readily accessible surface water, or areas where water abstraction must be limited due to ecological effects or slow recharge rates.

Catchments can provide water for crops, livestock, fish, wildlife, or other purposes by creating an impervious area with a large enough size to collect and store a substantial amount of water. The design of a water-harvesting catchment has common elements no matter the intended purpose of the capture water:

- A relatively smooth and impervious surface (compacted clay-rich soil, concrete, etc.) is used to direct water to the catchment (usually a pond, sometimes a subsurface tank).
- Sediment traps are installed upslope to ensure the longevity of the catchment.
- An overflow pipe or spillway prevent damage to surrounding areas in case of overflows.
- Fencing is often used to keep livestock out of irrigation water or for health reasons

Catchments require regular maintenance. They also pose potential adverse impacts, including risk of collapse and retention of water upstream in the watershed, to the possible detriment of other uses and users. (See for example, the USAID Programmatic Environmental Assessment: Rainwater Harvesting Infrastructure for Small/Medium-size Farms in Western and Southern Honduras). Except where well-proven indigenous systems exist (e.g. the micro-catchment rain water harvesting Zai system (Farming Africa, 2014)), they must be professionally designed and the design evaluated for local circumstances.

Construct and Maintain Diversions. A diversion is a long earthen embankment with a corresponding channel built across the slope to direct runoff water from, and to, a specific area. Diversions break up damaging volumes of runoff to reduce runoff and erosion damage, divert water away from vulnerable improvements, direct water to storage or harvesting systems, and can be used as supplemental water for conservation cropping systems.

Diversions are temporary structures that should have an expected life-span of no more than two years with no greater capacity than to handle an expected 24-hour storm. Channel designs can be parabolic, V-shaped, or trapezoidal depending on the stability of side slopes and maintenance requirements. The embankment height should be no smaller than 1m.

Diversions should not be used to collect sediment; therefore, appropriate sediment controls/traps should be used in conjunction with diversions. Further, a safe and stable outlet with an adequate capacity to handle expected volumes of diverted water must be established using vegetated areas or underground storage facilities. Any diversion channel or outlet should be vegetated using plants capable of stabilizing the soils of the diversion (NRCS, 2016; NRCS, 2015a). Like catchments, design and construction require engineering oversight.

Irrigated water management is addressed in Annex 1: Irrigation.

D.1.6 SAFER PESTICIDE USE, INCLUDING INTEGRATED PEST MANAGEMENT (IPM)

Crop production requires crop protection. Crop protection often requires use of pesticides which incur a set of environmental and human health risks. Safer Pesticide Use, which includes IPM, is the mitigation approach to these risks, and is described in D.4.

D.1.7 IMPLEMENTING MORE SUSTAINABLE AGRONOMIC PRACTICES

More sustainable agronomic practices are economically viable and promote long-term productivity, generally by conserving soil, sustaining soil fertility, and managing soil moisture. As such, these practices address multiple environmental impacts of cross production in a cross-cutting way. These practices are presented in three categories, and described further below:

- Crop residue management and tillage
- Planting Design
- Planting/Cropping

D.1.7.1 CROP RESIDUE MANAGEMENT AND TILLAGE

Note*: see section A.4.3 for discussion of tillage.*

Use Crop Residue as Soil Cover ("Crop Residue Management"). This practice leaves most crop residue in place *and unburned*, ideally resulting in at least a 60 percent cover of the soil surface at planting time. This amount of soil cover can protect soil from wind and rain erosion, add organic matter to the soil, conserve soil moisture, and improve infiltration, aeration, and tilth. It also reduces the need to manage crop residues as a waste. Unlike in conservation tillage (described below), crop residues may be incorporated into the soil by plowing at planting time. However, conservation tillage is also a form of crop residue management.

Note*: In some settings, crop residues are not necessarily 'residues', and may already be used for animal fodder.*

Crop residue can also harbor pests and diseases and are often burned or removed to prevent creation of pest/disease reservoirs. However, many pathogens that survive in or on crop residues can be managed through the strategic choice of crop sequence in a diverse rotation system (McGuire, 2000).

Potentially, Practice Conservation Tillage. No-till, or conservation tillage, is when most of the crop residue is left on the surface of the field after harvesting *and* soils are left undisturbed before planting. At the time of planting, disturbance is limited to opening a slot and placing seed.

Over years, a layer of crop residue remains on the soil surface, thereby protecting the soil from winds and rains while increasing the soil's capacity to absorb and retain water. The layer of crop residue also stabilizes soil moisture at a higher level and stabilizes temperature. The crop residue layer promotes the establishment of beneficial organisms (e.g. fungi, bacteria, insects) that decompose this material into new functional soil layers. Such biological tillage can only occur when mechanical tillage is not conducted (FAO, 2007).

Short of "pure" conservation tillage, there are several ways by which on-farm tillage can be significantly reduced by simply swapping from moldboard plows and disc-harrows to using chisel plows, or subsoilers, to implementing strip-till, zone-till, ridge-till, no-till, or permanent-bed systems. All reduce soil erosion and runoff of nutrients, improve water infiltration, and increase organic matter that maintains adequate soil moisture. Reduced tillage also causes less soil compaction.

However, conservation tillage usually controls weed growth through extensive use of herbicides and can require increased fertilizer inputs. These tradeoffs must be considered and their impacts mitigated. See D.4.2 and D.4.3.

Where Appropriate, Undertake Deep Tillage / Deep Plowing / Subsoiling / Ripping. This is a practice of tilling below the normal tillage depth (to a depth of approximately 0.7m) that modifies the physical and chemical structure of the soil. It is best suited for areas with poor quality lands (e.g. compacted or restrictive layers, overwash from flooding, or soil contamination). For these areas, it can help increase porosity and permeability of the soil to increase water absorption capacity (NRCS, 2012b). Deep plowing should not be done more frequently than every 3-4 years. It is often undertaken one time only when establishing orchards or implementing agroforestry schemes.

Plow on the Contour. Where tillage is practiced, soil should be plowed along the contour instead of up and down slopes. This reduces the velocity of runoff and thus more water is retained in the soils and distributed more equally across the cropland. This practice also reduces erosion, loss of nutrients, and sedimentation of nearby waters.

Implement Raised Beds, where Practical. Raised beds are planting areas (usually rectangular) that have 20-30cm of soil above nominal ground level. Raised beds improve soil drainage, reduce soil compaction, allow for earlier planting, and are useful for accessibility for people with disabilities and limited flexibility (Nair, 2016).

Carry Out Land Leveling, where Appropriate. Land leveling is a process of flattening or modifying existing slopes or undulations rather than necessarily creating a level surface (as the name may imply). A well-prepared and leveled field can reduce evaporation, restrict field runoff (which is important in cases with limited water availability), and optimize fertilizer and pesticide application. Land leveling requires careful assessment and engineering supervision.

D 1.7.2 PLANTING DESIGN

Manage Seeding/Planting Date. Seeding and planting date management is important in most circumstances and for most field crops. The optimal planting date helps achieve optimal crop development, supports insect pest management, and optimizes crop response to weather conditions. Selection of planting date can also have important impacts on crop yields.

Select Seed/Planting Materials Appropriately. Seed and planting material and varieties selection is a very important step in crop production (see A.4.2). New and improved varieties are developed to be more drought tolerant, resistant to water logging, tolerant to salinity, resistant to pests, more nutritious, and less perishable, among other beneficial qualities. A suitable crop variety can impact the overall water footprint in multiple ways such as reducing transpiration without lowering the yield and stabilizing the yield despite adverse conditions.

Note appropriate selection should include the mitigation measures outlined in D.4.1.

D 1.7.3 PLANTING /CROPPING

Note: *Not all of the measures and practices that follow can be implemented simultaneously; they must be evaluated for suitability given the local and program context.*

Rotate Crops; i.e. grow a series of dissimilar or different types of crops on the same land in sequential years. Rotations include cash crops, filler/ break crops, and cover crops. Break crops are secondary crops grown to interrupt repeated sowing of grain as part of crop rotation. Break crops are usually a pulse or oilseed crop grown instead of a cereal. Properly practiced, crop rotation reduces soil erosion, increases soil fertility and crop yield, improves soil structure and water holding capacity, and helps control pests and disease.

Determining a rotation schedule requires identification of rotation goals (e.g. maintain healthy soil, control diseases, increase profitability), resources and constraints, market trends, and farmer capabilities. See the USDA's Sustainable Agriculture Research and Education website for a table outlining how to manage a crop rotation system) (SARE, n.d.).

When crop rotation results in a farmer growing multiple crops concurrently, the farmer should become less susceptible to price fluctuations for any given crop.

Consider Polycropping/polyculture. Polycropping or polyculture is the practice of growing multiple crops in a given field simultaneously. To some degree, this system replicates the natural conditions of a plant's ecosystem and can lead to better nutrient and water utilization, higher crop resistance, and increased biodiversity. The system is also better able to meet nutritional demands of smallholders and reduce risks of production of a single crop. The increased complexity of polycropping/polyculture requires additional planning, control, labor, supervision, tools and equipment than for monocropping.

There are multiple types of polycropping:

- **Intercropping** consists of planting different species (e.g. maize and beans or cover crops and cereal rows) in the same field at the same time. It can be accomplished in different ways: 1) mixed intercropping, i.e. simply broadcasting seeds of all species types at the same time across the same area; 2) sowing the main crop in rows and then broadcasting secondary or cover crops across the field; or, 3) planting both the main and secondary crops in alternating rows. The benefits of intercropping include: the production of a variety of crops, improved soil fertility, and reduction of pests and weeds. Intercropping is often done with legumes or other nitrogen-fixing species (NRCS, 2015b).

- **Strip Cropping** consists of two (sometimes more) crops planted in alternating strips (usually 3-9m wide) in which each strip contains multiple rows of a single crop. Each season, the crop in each strip is rotated with a crop in a different strip. This system has similar advantages to intercropping but the use of strips makes harvesting crops easier than intercropping and reduces competition between crops (FAO, 2007).

- **Alley Cropping** consists of planting trees or shrubs in rows between the rows of crops to improve microclimatic conditions, reduce surface water runoff, improve soil health by cycling nutrients, increase carbon storage and air quality, increase crop diversity, and enhance beneficial wildlife and insect habitats. Fine hardwoods are often used in alley cropping systems as they can potentially provide high-value lumber or veneer logs while income is derived from a companion crop planted in the alleyways (Center for Agroforestry, n.d.). Otherwise, trees or shrubs should be compatible with the agroecological zone, have relatively deep roots, be relatively fast growing, contribute a valuable product, and not provide additional habitat for unwanted pests. Trees and shrubs are best used on or near contours to reduce water and wind erosion (NRCS, 2017; NRCS, 2010c). Alley cropping is used in mixed farming. See Section C.6 and refer to the Forestry SEG for additional information.

Note: *Polycropping is distinct from multiple cropping, a farming system in which farmers grow two or more crops in succession on the same field during one calendar year.*

Figure 14. Djenabou Camara works on her farm in Tougnifily, Boffa. Camara has improved her farm with better practices. She used to plant only eggplant, but with the new hybrid vegetable seeds and the intercropping techniques, she now grows okra and pepper as well. Credit: Ousmane Condé, USAID

Optimize Planting Density and Inter-Row Spacing. Using optimum planting densities to maximize yield is an important management tool for many crops. Optimal planting densities can improve final crop yields, water use, and resistance to pests. For example, with soybeans, planting density can affect plant growth, development, weed control, crop water use, and irrigation needs, and ultimately crop yield. Plant spacing is especially important for trees crops in order to minimize tree-to-tree competition for sunlight and water, while maximizing yield potential.

Grow Cover Crops. Cover crops are annually grown plants that protect and enrich soil, usually sown and grown between main planting seasons. Management and species selection allow for specific benefits to be derived from each selected cover crop, such as erosion control, excess nutrient uptake, increased soil nutrients and organic matter, and weed suppression (NRCS, n.d.).

Secondarily, cover crops can also help compensate for a main crop's failure. Such rapidly maturing/quick growing crops (e.g. radishes, spinach, rye, millet, buckwheat, or an annual legume) are considered "catch crops" (i.e. fast-growing crops that are grown between successive plantings of a main crop).

As with any crop, cover crops must be appropriate to the agro-ecological zone and consideration must be given to the labor and inputs entailed compared to the benefits gained. See (FAO 2011) for cover crop guidance.

Use Fallow Periods. Fallowing—i.e. leaving agricultural land uncultivated, usually for multiple growing seasons—was traditionally and in some places (where land is available) still is used by farmers to maintain land productivity. Benefits (Hamer, 2008) include rebalancing soil nutrients, and soil biota and interrupting crop pest and disease cycles. Fallowing land also may store water in the soil for a subsequent crop under rain-fed conditions.

Fallow land also provides wildlife habit—the longer the fallow period, the more benefits the crop field provides to neighboring ecosystems by supplying habitat and food sources.

Fallowing practice can include a longer-term planting of cover crops or fast-growing leguminous trees of more than a year. This has similar effects as cover cropping, but simply helps to rebuild soil over a longer period by building up organic matter and populations of beneficial soil microorganisms.

If deep-rooted crops are used during fallowing periods, those crops can move nutrients (e.g. potassium and phosphorus) closer to the soil surface.

Establish and Maintain Critical Area Plantings, i.e. planting and maintaining permanent vegetation on land where erosion is highly expected or has occurred frequently. This includes not just steep slopes, but degraded land where normal vegetation has difficulty thriving. By vegetating these areas, soils are stabilized, degraded areas are rehabilitated, and shorelines and riparian zones can be reinforced. Before planting occurs, it is important to specify the seed types, methods for seed preparation and seeding, and means of keeping the area vegetated. Grazing should not occur on critical planting areas if the site could be hazardous to people or animals and if the vegetation has yet to be established (typically at least two growing seasons) (NRCS, 2010d).

Establish and Maintain Field Borders. Field borders are strips at the edge or perimeter of an agricultural field that are permanently vegetated with a recommended minimum width of 10m. These strips reduce erosion from wind and rain, protect soil and water quality, manage pest populations, trap field runoff, buffer pesticide spray drift, provide wildlife and pollinator food and habitat, increase carbon storage, and improve air quality. Such areas can be used within a field, in between fields, or, most often, between agricultural lands and riparian zones (referred to as Zone 3 in the discussion on riparian zones in D.1.1.).

Plants selected for field borders must be appropriate for the agro-ecological zone. They should be planted in rows perpendicular to the direction of sheet flow and be able to withstand and slow sheet flow during heavy rains, be more attractive to pests than the crops they are protecting, have persistent roots, and—if possible—flower to attract and feed pollinators. Stiff-stemmed, upright grasses with a minimum height of 30cm are typical choices (NRCS, 2010e; NRCS, 2010f).

D.1.8 INTRODUCING AND PROMOTING GREENHOUSE AND URBAN AGRICULTURE

Greenhouse (Controlled Environment) Agricultural Production. A number of impacts of concern typical to field agriculture are eliminated or reduced with greenhouse ("controlled environment") production. For example, soil erosion is eliminated, and water needs and pesticide use are generally reduced. Greenhouse production is typically suitable for vegetables, berry and similar "compact" crops, but not for cereal crops requiring extensive planted areas for economic production. Greenhouse production has several varieties:

- *Traditional,* in which plants are grown in soil and watered with channel or drip irrigation
- *Hydroponics*, in which plants are grown in mineral nutrient solutions without soil to reduce or eliminate the risk of pathogens which present consistent public health concerns for vegetable crops
- *Aeroponic,* in which plants are grown in an airy or misty environment without the use of soil or an aggregate medium (known as geoponics)
- *Aquaponics,* in which aquatic animals (such as fish) are raised in a symbiotic environment with hydroponically grown plants

Greenhouse production entails capital costs that are out of reach for many smallholders. Beyond this, they may require additional energy input for ventilation and climate control. As built infrastructure, they also present the set of concerns typical of built structures.

Urban Agriculture brings food production—particularly vegetable crops—closer to urban communities by growing crops on rooftops, in vertical farming systems on the sides of buildings, in small backyard plots, in vacant lots, and in shipping containers (hydroponically using artificial light).

Urban agriculture reduces transportation costs in delivering food to urban centers and can increase availability of fresh vegetables. However, it also risks contamination of irrigation water (e.g. from urban surface drains), uptake of toxins from contaminated soils, and exposure of abutters to spray drift. These potential impacts must be considered and addressed.

"Shipping container farming" does not entail many of these impacts—but does require significant energy inputs, beyond its capital costs.

D.1.9 APPLYING MORE SUSTAINABLE AGRICULTURAL PRACTICES TO SPECIFIC CROPS

As documented in C.1.3, specific crops present different characteristic impacts of concern. The mitigation measures presented in the preceding sections should be prioritized to address these crop-specific impacts, as well as local conditions. For each crop, manuals and guidelines are generally available and should be consulted.

D.2 MITIGATING ADVERSE IMPACTS OF DEVELOPING THE ENABLING ENVIRONMENT

D.2.1 MITIGATION OF IMPACTS OF SUPPORT FOR AGRICULTURAL POLICY

Mitigation of agricultural policy impacts flows from an effort to identify these impacts, including perverse or unintended effects; see C.2.1. Such an analysis and indicated mitigations should be part of any policy support activity. Guidance for indicated mitigations is provided throughout this section D.

Beyond such specific mitigations, consideration may be given to strengthening governmental and social capacity for environmentally sound agricultural policy outcomes. Measures may include:

- Building awareness among policy makers about the importance of integrating environmental, social and ecosystem services considerations into policy decisions
- Providing technical training to legislative or ministry staff regarding the necessary analytical tools to support such integration
- Collaborating with civil society actors to strengthen ability of the civil society to influence policy
- Supporting efforts to bridge university research and expert knowledge in the policy making process
- Promoting media involvement in communicating policies and their potential social and environmental impacts

Note: *for concepts and best practices for agricultural policy programming generally, see Global Food Security Strategy Technical Guidance: Policy Programming*

D.2.2 MITIGATING IMPACTS OF SUPPORT FOR TRADE AND INVESTMENT

As stated in Section C.2.2, when investment increases the scale of production or results in a switch to more input-intensive production *without corresponding focus on environmentally sound production practices*, adverse environmental and/or social impacts are likely. This is particularly likely in countries where capacity to enforce environmental management standards is low.

To be environmentally and socially sound, policies and interventions stimulating trade and investment must identify and address these consequences, with reference to the mitigation measures presented throughout this Section D.

Note: *for concepts and best practices for agricultural trade programming generally see GFSS Global Food Security Strategy Technical Guidance: Agricultural Trade.*

D.2.3 MITIGATING IMPACTS OF SUPPORT FOR EXTENSION SERVICES

Extension services should promote crops/varieties and approaches that are proven *in practice* to be appropriate to the agro-ecological zone (see A.4.1) and farmer capabilities. This is a baseline requirement of responsible practice.

Mitigate based on the actions being promoted. Extension services focused on intensification. The adoption of cash crops or other endpoints that involve increased use of fertilizers, pesticides, or mechanization should incorporate/promote mitigations outlined in D.4.2–4, and also incorporate appropriate social mitigation as outlined in D.9.

Even if the sole focus of extension is land and soil management techniques intended to sustain or increase long-term farm productivity, extension services must, as indicated, incorporate/promote the mitigations outlined across D.1.

D.2.4 MITIGATION FOR SUPPORT FOR DATA, INFORMATION AND COMMUNICATIONS SYSTEMS

Where information is provided that is likely to result in a response from a producer, and such responses may present environment or health risks, information about safe and appropriate response should also be provided. Where risks may be specific and significant, associated technical or extension support should be made available.

For example, information regarding a pest outbreak could foreseeably lead to preventative spraying. In this case the information provided should also include recommended pest management measures, including—if pesticides use is indicated—suggested pesticides, dosage, and safer use precautions.

D.2.5 MITIGATING IMPACTS OF SUPPORT TO STRENGTHEN VALUE CHAINS

Where support has direct environmental or social impacts (this is described as "hard support" in C.2.5), mitigation measures will need to address these impacts. For example, strengthening food processing value chains via support to specific processors should include 1) identification of environmental/social compliance and performance deficits in the processors' operations and 2) training or assistance to address these deficits. Direct support to producers and enterprises should generally be conditional on their specific agreement to correct such deficits; see C.7.

Where "soft support" (see C.2.5) may result in indirect impacts associated with an increase in economic activity under one or more value chain segments, consideration must be given to mitigations that increase the general capacity of this value chain segment to operate in environmentally and socially sound ways – and/or of government to better support and enforce appropriate environmental and social performance.

> ***Note:*** *for concepts and best practices for crop production value chain programming see GFSS Global Food Security Strategy Technical Guidance: Market Systems and Value Chain Programming.*

D 2.6 POTENTIAL IMPACTS OF SUPPORT FOR CLIMATE ADAPTATION PLANNING

As noted in C.2.6, climate change adaptation measures for crop production differ widely in their technical nature and thus their impacts, ranging from strategies such as early planting to more structural interventions such as the developing water infrastructure.

Once potential impacts of the specific adaptation measure(s) are identified with reference to this or other SEGs, and with respect to the particular environmental and social context, they must then be mitigated—again, with reference to the guidance provided in this other SEGs.

D.3 MITIGATING ADVERSE IMPACTS OF BUILDING CROP PRODUCTION INFRASTRUCTURE

As noted in C.1, crop production activities may entail support to a wide variety of infrastructure, each with a characteristic set of potential impacts. Mitigation is likewise specific, and reference should be made as follows:

Aspect or type of infrastructure	Addressed in
Rural roads	Rural Roads SEG
Irrigation infrastructure	Annex 1 to this SEG
Use of insecticides, including soil treatments and wood preservatives in construction	Section C.4.3 of this SEG
General construction, including storage structures	Construction SEG, but also see C.4.6 regarding energy efficiency
Power	Energy SEG, but also see C.4.6 regarding energy efficiency
Terracing and other erosion control structures	Guidance not provided but see advisory and entailed reference in C.1.1.

Common mitigation requirements across all construction types include:

- Focus on occupational health and safety and fair labor practices including compliance with all host country requirements;
- Appropriate sourcing of construction materials; and
- Site-specific environmental and social review to inform site selection and design of specific mitigation measures, including identifying and addressing climate risks.

> ***Note**: For medium and large-scale construction, or construction in sensitive areas, USAID and/or host country requirements typically require a formal EIA scoping process, which in turn determines whether a full EIA study (for USAID activities, a 22 CFR 216 Environmental Assessment) is required.*

The need for professional engineering design and oversight is not an environmental and social mitigation per se, but engineering design should integrate any elements required for environmental and social risk mitigation. Engineering oversight includes oversight of construction site safety practices and materials sourcing.

D.4 MITIGATING ADVERSE IMPACTS OF USE OF AGRICULTURAL INPUTS

D.4.1 MITIGATION OF IMPACTS OF SUPPORT FOR/PROCUREMENT OF SEEDS AND PLANTING MATERIALS

When seeds and planting materials are used or procured—or their procurement, multiplication/ propagation or use is otherwise supported—care must be taken:

- Not to introduce invasive species or any species or variety new to cultivation in the area without appropriate host country review and approval. See Section D.1.2.
- To use only seeds and planting materials that meet host country sanitary and phytosanitary standards.
- To use only species/varieties known to be appropriate for the agro-climatic zone, including consideration of climate change.
- To educate producers regarding safe handling of treated seed—and to the extent such handling is under direct control of the project/activity – to enforce these practices.

The procurement or promotion, or training in use, of pesticides for nurseries, seed multiplication, treatment, or fumigation of seed is addressed in Section D.4.3. In addition, other impacts of nursery operations (such as waste) should be addressed.

Note: *Following FIFRA, USAID does not consider treated seed a pesticide per se and thus not subject to USAID's pesticide procedures. However, this is not a fully settled area of law: In the US, treated seed exemption under FIFRA (40 CFR Part 152, §152.25) has been successfully challenged in court.*

D.4.2 MITIGATION OF IMPACTS OF SUPPORT TO FERTILIZERS PROCUREMENT AND/OR USE

Use/Promote Fertilizers Consistent with 4R Principles and, Whenever Possible, Within an Integrated Soil Fertility Management (ISFM) Framework (see D.1.4). The "4R" principles of nutrient stewardship are: Right source, Right rate, Right time, and Right place (see figure below); applying fertilizers in the proper amount, at the right time of year, and with the right method with no overapplication significantly reduces the potential for soil degradation, and for pollution of ground and surface waters.

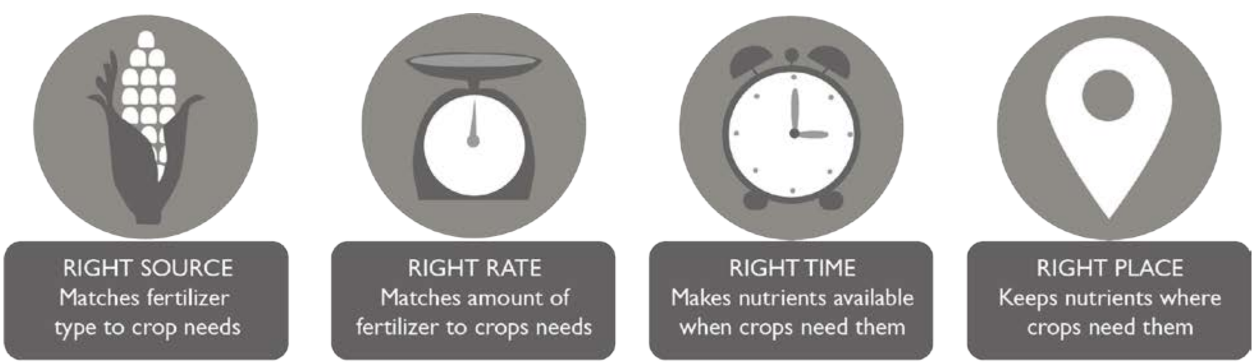


Figure 15. Basic principles of fertilizer stewardship (After The Fertilizer Institute/Nutrient Stewardship; www.nutrientstewardship.org)

Even where ISFM as such is not possible, fertilizer application should nonetheless be informed by a basic soil analysis. This is effectively required to implement 4R principles, specifically helping to tailor fertilizer composition and dosage to the actual requirements of the crop based on current nutrient availability in the soil.

In addition, key practices that reduce nutrient leaching, runoff and transport via soil should always be implemented. These may include:

- **Planting Cover Crops.** Planting certain grasses, grains, or clovers can help reduce runoff and nutrient loading by recycling excess nitrogen and reducing soil erosion. All cropped land, where soil conditions after harvest allow, should have either crop cover, grass cover, stubble cover, plowed surfaces, or a roughly cultivated surface. Fine seedbeds should only be created very close to sowing.
- **Maintaining Buffers and Borders.** Maintaining riparian buffers and field borders helps to absorb or filter out nutrients before they reach a water body. Buffers can also reduce pesticide spray drift and minimize soil erosion that can carry nutrients to surface waters. If such buffers/borders do not exist, set-back from waterways and drainage should still be observed when applying fertilizers – at least 10m, and 50m if the water is used for drinking.
- **Reduced Tillage.** Reducing the frequency of tillage reduces erosion and runoff and thus nutrient transport. It also reduces soil compaction, builds soil organic matter, and reduces GHG emissions.
- **Drainage Water Management.** Reducing nutrient levels of field drainage water (e.g., runoff) helps reduce nutrient loading of surface waters.

Each of these practices is discussed in section D.1.

Provide Training. Support for producer use of fertilizers must include training on safe and appropriate fertilizer use, including: understanding the nature of fertilizers used, the methods of application, the proper timing of application (see below), health and environmental risks of fertilizers, and appropriate storage and handling, including use of PPE (see below).

With respect to the last two points**,** training must include hazards awareness and communication. Warning must be provided that:

- Exposure to some fertilizers can cause eye and skin irritation and burns;
- Inhalation can result in irritation of the nose, throat, and lungs; and
- Nitrate levels above 10 mg/L (10 ppm) in groundwater can cause "blue baby syndrome" (acquired methemoglobinemia).

Provide and Require PPE. Farmers should always wear appropriate PPE when handling fertilizers. Where fertilizer is directly provided by a project, or directly controlled by a project, PPE should be provided and its use enforced.

Time Application Correctly. Fertilizers should not be applied during periods of heavy rain, waterlogging, or unusual climatic conditions when the dangers of leaching, or other barriers to immediate take-up, are high.

Store Fertilizers Separately and Safely. Fertilizers should be stored separately from food, seeds, pesticides, and animal feeds and away from any surface waters or drinking water supplies.

Maintain Distance. Application or storage of agrochemicals should be a suitable distance from any watercourse including ditches (e.g. 10m) or drinking water supplies (e.g. 50m), especially when handling or applying fertilizers, organic wastes, pesticides, or other chemicals.

Procure Quality Products. Procuring legal, reputable, well-labeled products helps to best assure that nutrient (N, P, K) concentrations are as advertised, and that the fertilizers do not have hazardous constituents.

Use Particular Care in the Context of Irrigation. The risk of groundwater pollution due to nitrate leaching is often high with irrigation schemes where high rates of N-containing fertilizers are used. Care must be taken with the amounts of nitrogen-containing fertilizers used in conjunction with irrigation. See Annex 1: Irrigation.

D.4.3 MITIGATING ADVERSE IMPACTS OF SUPPORT FOR CROP PROTECTION, PARTICULARLY PESTICIDES

Crop production requires crop protection. Crop protection often requires use of pesticides (see A.4.6), incurring a set of environmental and human health risks as described in C.4.3. Safer Pesticide Use, which includes IPM, is the mitigation approach to these risks, and is described in this section.

Safer Pesticide Use is the complex of practices over the entire pesticide "life cycle", from sourcing to container disposal, that (1) minimizes pesticide use to circumstances necessary to preserve food security or prevent economic losses, and (2) assures that when pesticides are used, the pesticides chosen and the manner in which they are used present as few risks as possible to people (producers, community members and consumers), other non-target organisms, and the environment.

Safer pesticide use requires at least all of the following:

- Use of pesticides within an IPM framework (see below);
- Procurement of quality product labeled in a manner compliant with FAO-WHO guidance (at minimum) in a language that can read by the applicator (FAO-WHO 2015);
- Use of non-expired product that is legal in the host country;
- Use per label, including:
    - Correct use of specified, well-maintained PPE
    - Correct dilution/dosage and application equipment
    - Employment for specified uses only
    - Observation of specified pre-harvest/re-entry intervals
    - Observation of environmental and storage precautions
- Use of well-maintained, properly calibrated, leak-free application equipment employed with proper technique;

- Practices to reduce spray drift, volatilization, and water pollution, including but not limited to: application in morning or evening and in minimum-wind conditions, observation of set-backs from surface waters (usually at least 35m), and no application when very wet conditions are anticipated, etc. (NPIC, 2017) (UNL Water, n.d.);
- Transport, storage, handling, mixing, clean-up and disposal conducted in a manner to minimize spills, human and environmental exposure. If spills occur they are contained;
- Individuals trained in pesticide exposure first aid close at hand, and access to medical facilities whose personnel are trained and equipped to respond to pesticide poisoning; and
- Communication of risks to bystanders, including warning signage.

Integrated Pest Management (IPM). (See A.4.6 for definition of IPM.) IPM is considered an effective way to manage pests while minimizing harm to humans, other non-target organisms and the environment. The essential elements of IPM are:

- Determination of an "economic threshold" or the level of pest damage that is great enough to justify the cost of implementing control measures;
- Monitoring of pests and damage levels;
- Use of pesticides only when practicable (i.e., when non-pesticidal methods do not keep pests below this economic threshold (EPA, 2017b)); and
- Use of pesticides chosen for efficacy, selectiveness, and lowest risk of adverse health and environmental impact in the given context.

Generally speaking, practices to improve plant health and integrate soil fertility management provide the baseline conditions for IPM success, because healthy crops grown in fertile soils may be less susceptible to pests (see D.1.4 and D.1.7). On top of such baseline practices, IPM utilizes the following types of non-pesticidal crop protection measures:

- *Cultural pest control* is the use of farming or cultural practices that make the crop environment less favorable to pest species—for example, choosing sowing and harvest dates that minimize damage; intercropping; vegetation management, crop rotations, trap cropping, destruction of volunteer plants, and weed management.
- *Biological control* is the manipulation, conservation, or introduction of the natural enemies of predators, parasites, or pathogens. Implications for introduction of invasive species may need to be considered when developing and promoting introduction of biological controls.

As noted previously, introduction of exotic predator species carries significant risks:

- *Physical and mechanical control* is the application of direct or indirect measures that kill the pest; disrupt its physiology by means other than using chemicals; exclude it from an area; or adversely alter the pest's environment, such as picking out pests, trapping, shaking pests off, pruning of branches, defoliation, thinning and topping.
- *Host plant resistance* is the breeding and use of crop varieties that are less susceptible to pests like insects, diseases, nematodes, parasitic weed, and birds.

- *Legal/regulatory control* includes the enforcement of measures and policies that range from quarantine to land and water management practices. These policies include the prevention of the entry and establishment of undesirable plant and animal pests in a country or area, and eradication, containment, or suppression of pests already established in limited areas (quarantines). This approach to pest management must involve area-wide operations that include many rural households and are enacted for the common good of both farmers and society at large.

Development of an IPM strategy—i.e. a place-specific protocol for implementing IPM with respect to specific crops and pests of economic importance—formally requires the following steps.

1. Identify the major pests, quantify losses caused by them in a given agro-ecosystem, and determine the economic thresholds;
2. Study the biology, behavior, and population dynamics of the pests to understand the features that can be exploited for pest management;
3. Establish the role of local natural enemies and develop mass-rearing, or mass-culture for disease agents on insects;
4. Study and develop other suitable components of IPM, such as intercropping and other cultural practices;
5. Integrate these components into an appropriate IPM technology and test for compatibility and efficacy under varied ecological conditions; and
6. Develop a simple protocol for monitoring the impact of IPM technology in the field.

Reduced-form Approaches to IPM are Still Beneficial. Where technical capacity or resources for the above steps are lacking, less rigorous or reduced-form approaches to IPM are still beneficial compared to "calendar spraying" (i.e. applying pesticides on a regular basis whether pests are present or not) or simply responding to infestations reactively, after damage has occurred.

At minimum, less rigorous approaches to IPM involve: (1) practices to improve plant health and integrated soil fertility management; (2) use of resistant varieties, when available; (3) routine measures to prevent build-up of pest populations, such as crop rotation for annual crops or dormant season spraying with mineral oil for tree crops; (4) not killing beneficial predators with inappropriate pesticide application; (5) incorporation of practical non-chemical controls for pests of economic importance into cultivation practice (usually as recommended by agricultural research/extension organizations); and with these practices in place, (6) monitoring for pest density/damage and (7) only when required, using a pesticide chosen for a combination of efficacy and safety.

> ***Note:*** *See the Feed the Future Fall Armyworm IPM Guide for Africa for an example of IPM tools and strategies applied to a pest of critical economic importance: (Prasanna et al, 2018. Available at https://www.usaid.gov/sites/default/files/documents/1867/Fall-Armyworm-IPM-Guide-for-Africa-Jan_30-2018.pdf.)*
>
> *The above discussion of IPM is written to the context of crop production. IPM is also applicable to commodity protection (i.e. the protection of crops in post-harvest storage). For example, good housekeeping/sanitation and maintenance of storage structures are essential complements to the use of pesticides to protect stored commodities.*

Achieving Safer Pesticide Use in Practice requires motivation (i.e. understanding of pesticide risks to people and the environment); practical training; availability of quality pesticides, PPE, and application equipment; technical assistance; monitoring; and the capacity and resources to implement at least reduced-form approaches to IPM.

Where projects are directly procuring and using pesticides and thus have a high degree of control, it is incumbent upon them to assure a high standard of safer use. When projects are rather supporting the procurement or use of pesticides indirectly (e.g. via extension recommendations, credit provision, etc.) and do not have direct control over the pesticides chosen and how they are used, the emphasis should be on ensuring that the prerequisites for safer use are in place, that training is provided, and that assistance and benefits are tied wherever practicable to pesticide safer use.

BOX 6. USAID'S PESTICIDE PROCEDURES

Support to the procurement and/or use of pesticides on USAID-funded or managed activities requires compliance with the Agency's pesticide procedures, 22 CFR 216.3(b). Such support is broadly defined by USAID as any direct and indirect support for pesticides, including support for pesticide input value chains. The purpose of these procedures is to best assure safer pesticide use.

In general, the procedures require that *each pesticide* to be supported must be approved on the basis of 12 evaluation factors:

> (a) The US EPA registration status of the requested pesticide; (b) The basis for selection of the requested pesticide; (c) **The extent to which the proposed pesticide use is part of an integrated pest management program** [emphasis added]; (d) The proposed method or methods of application, including availability of appropriate application and safety equipment; (e) Any acute and long-term toxicological hazards, either human or environmental, associated with the proposed use and measures available to minimize such hazards; (f) The effectiveness of the requested pesticide for the proposed use; (g) Compatibility of the proposed pesticide with target and nontarget ecosystems; (h) The conditions under which the pesticide is to be used, including climate, flora, fauna, geography, hydrology, and soils; (i) The availability and effectiveness of other pesticides or nonchemical control methods; (j) The requesting country's ability to regulate or control the distribution, storage, use and disposal of the requested pesticide; (k) The provisions made for training of users and applicators; and (l) The provisions made for monitoring the use and effectiveness of the pesticide.

These factors and the procedures overall heavily reference and rely on the US EPA registration status of and registered used for the subject pesticide. More rigorous analytical requirements apply to pesticides designated by US EPA as restricted-use. Additional research is required when a pesticide is not approved by US EPA for same or similar uses.

The **Pesticide Evaluation Report and Safer Use Action Plan (PERSUAP)** is the process and instrument by which these analytical requirements are addressed. As such, PERSUAPs establish the pesticides for which support to procurement and/or use is approved, and specific, mandatory safer use conditions. The approval is provided for specified activities, sectors, uses, value chains, geographies, and for specified time limits. Once approved by both the USAID mission or office director and the cognizant BEO, the safer use conditions they establish become binding on activity implementation.

PERSUAPs consist of two parts: the PER, which provides the 12-factor analysis and related background information; and (2) the SUAP which provides the list of approved pesticides, approved uses, and safer use conditions. Some conditions are specific to a single pesticide; others are general. The SUAP flows from the PER analysis. Its safer use conditions typically cover all elements of safer use set out above, including required implementation of IPM in some form. The SUAP commonly includes recommended chemical and non-chemical controls for pests of economic importance affecting the value chains covered by the PERSUAP; these are provided as resources for IPs to use in finalizing and implementing their required IPM plans.

Implementation of the SUAP is the responsibility of the implementing partner, who must have both the technical capacity and resources under the activity budget to do so.

Note: *USAID-supported phosphine fumigation of food commodities must comply with the requirements of USAID's Programmatic Environmental Assessment for Phosphine Fumigation of Stored Agricultural Commodity*.

D.4.4 MITIGATING IMPACTS OF SUPPORT FOR TOOLS AND MECHANIZATION

The impacts associated with the introduction of new tools and machines vary widely depending on type and use context. The mitigations below should be employed as applicable.

Use Lighter Equipment, where Needed. Where soil is highly compactable or landscape features fragile, lighter equipment, animal traction and/or hand tools should be employed rather than heavy equipment. See the Livestock SEG for management of the impacts of livestock.

Provision of land clearing/logging equipment requires detailed assessment to define its environmentally sound intended use and strict controls and monitoring to assure that the intended use and only the intended use results; see D.1.1: "Support Land Clearing Only With Detailed Assessment and Thorough Mitigation."

Note: *On USAID-funded activities, provision of logging equipment is forbidden by Section 118 of the US Foreign Assistance Act (FAA 118) except when a full EIA study (22 CFR 216 Environmental Assessment) demonstrates that all timber harvesting operations involved will be conducted in an environmentally sound manner that minimizes forest destruction, and that the proposed activity will produce positive economic benefits and sustainable forest management systems.*

Provision of pesticide application equipment constitutes support for the use of pesticides and should therefore be addressed as described in D.4.3, above.

Store Fuels and Oils Properly. To reduce the possibility of fire and explosion, fuels and oils should be stored away from sources of ignition (e.g. kitchens, work yards) in non-flammable tanks/structures.

To reduce risk of soil, surface water and groundwater contamination, tanks should be above ground. Storage structures should be built with spill containment and not be in riparian buffer zones (see D.1.1) or in areas prone to flooding or waterlogging.

Maintain Equipment/Plan for Maintenance. Both for safety and to reduce GHG and other pollutant emissions, powered equipment should be maintained—or when provided and handed over, there should be a plan and capacity for maintenance, including availability of spare parts.

Use PPE and Teach Safe Operation. If equipment is provided or its purchase facilitated, appropriate PPE should be provided as well, and its use enforced when equipment operation is under direct project control. Training should include operator and bystander safety.

Screen New Tools and Technologies. All introductions of new technologies and machinery should be reviewed for environmental and social impacts over the lifetime the equipment is to be used, and appropriate mitigations beyond the minimum set enumerated on this basis.

D.4.5 MITIGATING IMPACT OF IRRIGATION ACTIVITIES

Mitigating the impacts of irrigation on land is addressed in summary form in Section D.1.1. Managing pollution from irrigation is addressed in summary form in Section D.1.3. Irrigation impacts and mitigation measures are addressed in more depth in Annex 1: Irrigation.

D.4.6 REDUCING THE IMPACT OF ENERGY USE IN CROP PRODUCTION

There are four primary approaches to reducing the impact of energy used in crop production: (1) use efficient, clean-burning equipment; (2) use synthetic fertilizers only as required; (3) use renewable energy sources; and (4) sequester carbon on agricultural lands. Each is discussed below.

Use Efficient, Clean-burning Equipment. Equipment that is efficient requires less fuel or energy per unit of output—meaning that less fuel is burned, and consequently emissions and impacts are reduced. Equipment that is clean-burning also emits fewer non-GHG air pollutants. There are three ways to best assure that equipment is as efficient and clean-burning as practicable:

- **Maintain Equipment.** Equipment that is well-maintained is more energy-efficient and cleaner-burning.
- **Use Equipment of Appropriate Size/Capacity**. Equipment that is the appropriate size will run at its optimal efficiency, assuming it is well-maintained.
- **Start with Efficient, Clean Equipment.** There is often a wide range of energy efficiency and emissions performance within a given type of equipment. Starting with equipment that is as efficient and clean-burning (as practicable and maintainable in the local context) significantly reduces emissions and fuel use over the lifetime of the equipment.

Use Synthetic Fertilizers Consistent with 4R Principles. Synthetic fertilizers require a very large energy input to manufacture and transport. Using/promoting synthetic fertilizers consistent with 4R principles and within an ISFM framework (see D.4.2 and D.1.4) will result in minimum necessary use of synthetic fertilizers, increasing the energy efficiency of the overall crop production system.

Use Renewable Energy Sources. After solar energy for photosynthesis, fossil fuels are currently the primary energy source in agriculture. Use of renewable energy sources, when possible, can avoid many of the GHG emissions and other environmental impacts of fossil fuel use. The renewables most often available in crop production contexts are as follows; see the Energy SEG for more information.

- **Biogas** is impure methane obtained from the anaerobic breakdown of organic material. Most frequently, the source material is animal waste or mixed municipal waste (e.g. in landfills), though plant material may be used as well. Biogas may be used to run engines (including for power generation) or dryers, or otherwise substitute for natural gas. Assuming the source material would otherwise be waste, biogas generally has strong environmental benefits—not only does it have close to "net-zero" carbon emissions, but in using material that would otherwise be waste, it reduces methane emissions and water and soil pollution.

- **Biofuels other than biogas**—primarily ethanol and biodiesel—tend to be produced from large-scale monoculture plantations of maize or sugarcane (ethanol) or soybeans and palm oil (biodiesel). Where such fuels are available, they can be used as gasoline or diesel would be. However, use of ethanol rather than gasoline requires equipment modifications.

  The environmental costs and benefits for biofuels are more complex than biogas. Growing crops for the purpose of manufacturing biofuels (e.g. sugar cane for ethanol) is crop production and entails all of the impacts discussed throughout Section C and addressed in this Section D—for example, palm oil cultivation in Southeast Asia to support biodiesel production, in particular, is associated with deforestation, peatlands degradation, and loss of habitat and biodiversity. In addition, crop production for biofuel may divert arable land or water resources away from food production.

- **Wind and Solar.** Wind can produce electricity via a turbine, or a windmill can provide direct mechanical power for pumping. Solar insolation can produce electricity (via photovoltaic (PV) panels) or be used directly for hot water or heat. In either case, the emissions that would otherwise result from using fossil fuels for these purposes are eliminated. However, wind and solar do have environmental impacts (including through their manufacturing), though those of small installations are usually minor. Other considerations are capital cost, the intrinsically intermittent nature of these resources, and average level of supply.

Sequester Carbon. Increasing the carbon stored in a farm's soil and long-term biomass can partially offset the carbon emissions that result from energy inputs to crop production. In general, mitigation measures presented to preserve land and landscapes (see D1.1) sustain soil fertility (see D.1.4) and many of the more sustainable practices presented in D.1.9 increase soil carbon. Live biomass is increased by practices that maintain perennial groundcover and hedge and erosion control plants such as *Vetiver,* and particularly by trees in mixed farming systems (see D.6).

D.5 MITIGATING IMPACTS OF CROP PRODUCTION RESEARCH AND INNOVATION

Section C.5 classified innovation and R&D activities into field and farm information gathering survey activities, sampling and research conducted in facilities that do not require physical containment, containment facility research including GM/GE research, field trials, and dissemination of research information. Appropriate mitigation is different for each:

Field and farmer surveys have negligible environmental impacts and will not require environmental mitigation measures.

Surveys and Research that Entail Collection of Physical Samples and Laboratory Experiments and Analysis. Any physical sampling should be as conducted per a field manual or operating procedure addressing field team safety in addition to sample quality and integrity; this should be part of the survey or research design. As part of any bid or quotation for laboratory services, respondents should be required to provide their standard operating procedure (SOP) for the analytical work in question and to describe environment, health and safety (EHS) systems, in place and their EHS compliance status, as relevant. At minimum, bids should not be awarded to laboratories unable to document compliance with host country requirements or to provide an SOP.

In addition, sampling involving endangered species or for gene prospecting purposes must generally be reviewed and approved by host country authorities. Where this is not required or where host country capability is low, appropriate USG agencies or international organizations should be consulted for sound study design.

Containment Facility Research Such as Plant Pathology, Entomology, and Plant Breeding. Containment facilities operate at different, risk-based biosafety levels; each progressive level has more rigorous physical and procedural containment requirements. The definition of these levels and these requirements is beyond the scope of this document; see for example FAO, 2011.

Containment facilities and/or the research they conduct usually requires a license or permit from host country authorities; even with such a license, containment facility research should only be supported with a documented, independently reviewed risk assessment to determine the risk level, and independent expert site audits to verify conformity of the facility with requirements.

Containment Facility GM/GE Research. The above discussion of containment facility research applies to the specific case of containment facility research with GM/GE organisms. In this case, components of the risk assessment include the GM/GE organism's safety for food and animal feed (including potential toxicity, pathogenicity, allergenicity, or nutritional changes) and safety for the environment including potential for weedy or invasive persistence, unintended gene flow to other organisms, or impact on non-target organisms. Compliance with host country policy, statute or regulation is a minimum requirement—absent elaborated host country requirements, such research should not be supported. Beyond the existence of such requirements, host country capacity to effectively regulate the proposed research is also a key consideration.

Note: *All USAID actions involving GM/GE organisms are subject to USAID's Biosafety Review Procedures, set out in ADS 211. The USAID Agency Biosafety Officer (ABO, located in the Bureau for Food Security) and relevant BEO must be consulted early in the process.*

Field Trials. As noted in C.5, (1) there are particular risks to ecosystems and/or existing genetic resources with field trials involve a crop, biological control, or other species new to the cultivation zone; and (2) addressing these risks is one important function of the earlier stages of the innovation process, well before the point of field trial. Before beginning any field trial, it must be confirmed that these risks have been duly considered. If they have not, a formal risk assessment should be undertaken and fully taken onboard; any required host country approvals must be obtained.

Field trials then incorporate relevant general and specific crop production mitigation measures as described in Section D.1 and D.4. In addition, contained and open field trials of GM/GE organisms will entail specific, additional monitoring requirements; see for example FAO, 2011.

Scaling and Dissemination of Innovations. The required mitigation measures will depend on the specific innovation being promoted and the anticipated scale of adoption. Where activities involve a mix of demonstration plots, extension services and input provision, mitigation measures are outlined in D.1., D.2.4, and D.4. Demonstrations and dissemination of innovations must build awareness about the environmental and social impacts of these innovations.

D.6 MITIGATING IMPACTS OF MIXED FARMING SYSTEMS AND AGROFORESTRY

Mitigation measures for agroforestry are addressed in the Forestry SEG. Section D.1.7 provides brief descriptions and considerations attendant to polyculture systems. This section therefore focuses on mixed farming systems that include livestock.

Mixed farming systems that include livestock are generally considered more sustainable than systems that include one or only a few crops. This is because manure produced by farm animals in a mixed/livestock farming system is an asset for farmers when collected, stored, and used properly as a soil amendment or fertilizer.

However, large-scale, intensive livestock systems can result in over-application of manure if not managed properly. Too much manure, like too much fertilizer, or inappropriately applied mineral fertilizer, can result in soil nutrient loss through leaching or through runoff with soil erosion.

To prevent adverse impacts of manure use in a mixed farming system, several practices should be followed:

1. Properly store manure, whether liquid or solid, until the manure is field applied. Proper storage protects the manure from the environment, maintains its nutrient content, and reduces odor and insect infestations that can result from stored manure.

2. Identify appropriate crop fields where the manure will be applied. Manure application rates should be adjusted for soil type, soil analysis, and crop needs.

3. Rotate manured fields so the farm's manure is not repeatedly applied to the same area. This reduces the potential for over-application of crop nutrients and subsequent nutrient losses.

4. Use good manure application techniques to stabilize the manure and manure nutrients in the soil, preferably by immediate incorporation of the manure into the soil.

D.7 MITIGATING ADVERSE IMPACTS IN HARVEST, POST-HARVEST, STORAGE AND FOOD PROCESSING

> ***Note:*** *The six mitigation categories presented in this section are generally not severable. All are required to address the range of impacts presented by most support to the harvest and post-harvest segments of the crop production value chain.*

1. **Research and Apply Relevant Innovations in More Sustainable Harvest and Post-harvest Practices**. Such practices reduce crop losses, preserve food, reduce contamination, and/or increase food safety while increasing efficiency, controlling costs, and conserving energy. Examples of more sustainable postharvest practices include the modification of harvesting procedures, such as harvest time, or strip harvesting (where crops are harvested in alternate strips), so that two different-aged growths occur simultaneously in a field.

   Expensive and complex postharvest technologies can be difficult for smallholders to adopt. Therefore, it is likely more advantageous to consider small-scale postharvest tools and innovations (Kitinoja, 2013). For example, the Purdue Improved Crop Storage (PICS) technology is a sealed, triple-layer plastic bag for smallholder storage of grain. It creates hermetic conditions to substantially reduce or eliminate insect damage in storage of dry grain without insecticides (Murdock and Baoua, 2014).

2. **Inspect to Identify EHS and Food Safety Deficits, Make Support Conditional on Corrections.** Where support is provided to specific existing facilities or operations (referred to as "hard support" in C.2.5), conduct a pre-support environment, occupational health/safety and food safety inspection to identify compliance and performance deficits. Consider providing technical assistance or training to address these deficits. In any case, direct support to facilities and operations should generally be conditional on their specific agreement to correct such deficits.

   Where support is rather provided in a more general way to this value chain segment ("soft support," see C.2.5), EHS and food safety deficits across the segment should be characterized generally, and actions incorporated into activity design to help address these deficits. This may include support to government capacity to better support and enforce appropriate EHS and food safety performance. (See "Promote Food Safety," below.)

   Note: *A resource-efficient and cleaner production (RECP) approach can often provide approaches that benefit both business and EHS performance. See immediately below.*

3. **Review and Apply as Relevant the Food Processing RECP Briefing and Resource Guide.** Part of the USAID SEG series, this document provides guidance for identifying and addressing unhealthy working conditions, excess water use, poor process control, inadequate machinery maintenance, and liquid and solid wastes within a RECP framework. RECP interventions focus on (1) increasing the efficiency with which resources are utilized and/or (2) assuring that resources are utilized "cleanly"—without incurring costs and impacts that adversely affect the bottom line of the enterprise, the environment, and worker and community health and safety. The RECP briefing is focused on food processing and MSMEs but has significant applicability to storage and logistics operations as well, and at larger scales.

4. **Promote Food Safety.** A consistent, robust focus on food safety is essential to mitigating the risks to public health intrinsic in crop harvest, handling, storage, and processing operations. The form this take depends on the specific facilities, operations, and/or actors being supported. However, in the private sector, the emphasis will generally be on implementation of recognized management systems that incorporate the key food safety principles of hygiene, prevention, risk reduction, reliability, consistency, traceability, customer and consumer relevance, transparency, and accountability. For example, Hazard Analysis and Critical Control Points (HACCP) is a systematic preventive approach to food safety from biological, chemical, and physical hazards in production processes. In many cases, supporting certification to particular systems or schemes is appropriate. See also A.4.9.

   Alternately or in addition, actions may need to focus on:

   - Building governmental capacity to establish and enforce standards;
   - Building and strengthening consumer and professional organizations that play a supporting role in informing policy;
   - Collaborating with academic institutions who engage in relevant research and education; and/or
   - Building awareness to make consumers cognizant of the level of safety associated with the foods they purchase and how they should store foods (FAO, n.d.(e)).

5. **Identify relevant aspects of the support listed below, and consider the indicated mitigation measures**:

   - **Infrastructure Aspects, Including Fuel Storage.** Support to construction of logistics, storage/warehousing, and food processing facilities is support to crop production infrastructure and is addressed in D.3 and its on-references, particularly the Construction SEG.

     Where fuels or oils must be stored in or near facilities, see also D.4.4.

     > ***Note:*** *Similar to other large structures, large food warehousing, logistics, food processing, or cold storage projects may require scoping and, potentially, full Environmental Assessments (EIA studies) under USAID and/or host country procedures.*

   - **Energy Consumption Aspects.** To the extent that support is for transport equipment, mechanization or cold chains, the impacts of energy use are a concern. Mitigations are presented in D.4.6 and in particular, under the sub-heading "Use efficient, clean-burning equipment."

   - **Pest Control Aspects.** To the extent that support involves support to pest management or the operations supported require pest management, safer pesticide use is a required mitigation strategy—see D.4.3. In the structural context, IPM includes good sanitation practices, pest-resistant storage (see PICS example, above), and in some cases, biological controls (for example, the use of cats to control rodents).

***As noted in D.4.3**: (1) USAID's pesticide procedures apply not just to field production, but to structural pest control and pest management in stored commodities; and (2) USAID-supported phosphine fumigation of food commodities must conform to the requirements of the agency's USAID's Programmatic Environmental Assessment for Phosphine Fumigation of Stored Agricultural Commodity.*

- **Safety Aspects Beyond Structure Design**. Harvest, logistics, storage/warehousing, and food processing operations can present significant health and safety risks, for which mitigations are presented in D.4.4 under "Maintain Equipment/Plan for Maintenance" and "Use PPE and Teach Safe Operation."

- **Waste Aspects.** Where supported facilities or operations will generate wastes, a waste minimization and management plan should be in place, identifying the most environmentally sound practicable disposal option for the subject waste stream(s).

6. **Screen New Tools and Technologies.** All introductions of new technologies and machinery should be reviewed for environmental and social impacts over the lifetime the equipment is to be used, and appropriate mitigations beyond the minimum set enumerated above developed on this basis.

D.8 MITIGATION AND DESIGN CONSIDERATIONS FOR CROP PRODUCTION SUPPORT IN THE CONTEXT OF NUTRITION, DISASTER RISK REDUCTION, AND SUPPORT TO MSMES

D.8.1 MITIGATION IN THE CONTEXT OF CROP PRODUCTION AND NUTRITION

Achieving nutritional benefits and avoiding unintended adverse effects on nutrition via support to crop production generally requires the following:

Integrate a focus on nutritionally diverse production, as focus on a single crop may raise income or increase caloric food security, but not translate to overall nutrition. For example, where appropriate, a focus on vegetable gardens could be incorporated to both diversify family diet and improve incomes.

Integrate Nutritional Awareness and Education. Beyond awareness of good nutrition and its importance, community and household awareness about the connection between health, nutrition, and how food is grown is key to translating income gains to improved nutritional status. This includes awareness of the importance of growing crops in clean soil, observing pre-harvest intervals, and managing fertilizer correctly. With respect to the last, growing crops on polluted soils or with too high a level of fertilization may lead to contamination of certain sensitive crops, resulting in excessive levels of, for example, nitrate or cadmium.

Assure benefits accrue to women, as there is a direct link between women's control over income and better maternal and child nutrition.

Focus on soil health and safer pesticide use to maximize the nutritional content of crops produced and to avoid unhealthful pesticide residues. See D.1.4 regarding mitigation measures for soil health and D.4.3 regarding safer pesticide use.

Avoid Incentivizing Displacement. As noted in C.9, crop production activities can create an economic incentive to convert land to alternate, higher-value uses (e.g. for cultivation of a cash crop). Where this displaces poorer or more vulnerable members of the community, adverse nutritional consequences are likely. See D.9.

> ***Note:*** *For key concepts and best practices for nutrition programming generally, see Global Food Security Strategy Technical Guidance: Objective 3. A Well-Nourished Population, Especially Women and Children. The above mitigation measures address nutrition specifically. The adverse impacts of support for crop production in any context should be mitigated as described throughout this Section D.*

D.8.2 MITIGATION IN THE CONTEXT OF CROP PRODUCTION DISASTER RISK REDUCTION

As noted in C.8.2, many crop production DRR practices—such as use of drought and/or flood-tolerant varieties, mulching and other water conservation measures, and use of compost—have environmental co-benefits such as improved soil health, reduced pollution, and increased carbon sequestration.

This said, promotion of any crop or farming system can have adverse impacts, which should be addressed as elaborated throughout this section D. This includes but is by no means limited to assuring that the crops/varieties and practices promoted are proven in practice to be appropriate to the agro-ecological zone (see A.4.1) and farmer capabilities.

To the extent that DRR activities include construction or rehabilitation (e.g. of storm-resistant crop production infrastructure), the mitigation measures for support to crop production infrastructure apply (see D.3).

> ***Note:*** *For crop production resilience programming concepts and best practices, see Global Food Security Strategy Technical Guidance: Objective 2. Strengthened Resilience Among People and Systems.*

D 8.3 MITIGATION IN THE CONTEXT OF SUPPORT FOR MSMES IN THE CROP PRODUCTION VALUE CHAIN

As noted in C.8.3., the potential impacts of support to MSMEs in any given segment of the crop production value chain are no different from the impacts of other types of support to the segment in question. As such, mitigations are covered elsewhere in this Section D and depend on the MSME's function within the crop production value chain and the nature of support provided (e.g. business and/or technical capacity building, direct technical support, provision of equipment and services, support for infrastructure, credit support).

For mitigation of support to harvest, post-harvest, logistics, storage, marketing, and food processing MSMEs, see Section D.7. For mitigation of impacts of supporting input supply MSMEs, see section D.4. Resource-Efficient and Cleaner Production (RECP) approaches (see D.7) often are particularly appropriate for MSMEs.

Given that MSMEs often have low awareness of and capacity for environmentally and socially sound practices, building such awareness and capacity should be an integral component of all mitigation approaches.

D.8.4 MITIGATION IN THE CONTEXT OF CROP PRODUCTION AND NRM INTEGRATION

Define Impacts via a Specific Environmental Review with an Ecosystem Services Lens. As noted in Section C.8.4, a specific environmental review, examining the environmental context of the intervention and the specific practices and crops to be promoted, is usually required to understand and address the potential impacts of integration of NRM with crop production activities.

Such an environmental review should include a specific ecosystem services focus (see C.9.4), as it is such services that NRM seeks to sustain. See USAID's Environmental Compliance Factsheet: Ecosystem Services in Environmental Impact Assessment for more information.

Mitigate as Indicated Throughout this Section D. As noted in C.8.4, adverse environmental and social impacts are possible in the context of integrated NRM and crop production activities, just as they are with support to any crop and cropping system. Based on the impacts identified in the environmental review, mitigations should be designed and implemented consistent with this section D.

> ***Note:*** *For key concepts and best practices for resilience elements of integrated crop production-NRM programming, see Global Food Security Strategy Technical Guidance: Objective 2. Strengthened Resilience Among People and Systems.*

D.9 ADDRESSING SOCIAL IMPACTS AND CONSIDERATIONS IN CROP PRODUCTION

Fair treatment and good working conditions are integral components of sustainable crop production.

Occupational and community safety and health issues are integrated into the foregoing sections and not addressed separately in this section. However, the following is a basis for effective mitigation of occupational and community health and safety risks:

Address Occupational and Community Health and Safety in the Pre-implementation ESIA Process. Pre-implementation environmental and social impact assessment (ESIA) processes (e.g. USAID IEEs and EAs) should specifically address occupational and community safety and health risks presented by supported activities—for example those presented by use of equipment, fertilizer and pesticides. Such analysis should specifically (1) consider the risks presented to more vulnerable members of the community (such as children, women, and individuals with weakened immune systems); and (2) identify and follow any host country or international occupational health and safety standards that apply. Mitigation design, with reference to occupational safety and health issues as addressed throughout this section D, should then address the risks so identified.

D.9.1 MITIGATION OF ADVERSE IMPACTS ON WOMEN AND VULNERABLE GROUPS.

Undertake Pre-implementation Gender and Related Social Analyses; Design & Implement Mitigation Accordingly. Gender analysis (mandatory for USAID activities per USAID ADS 205) is essential to understanding how the economic, food security, and nutritional benefits—and the potential adverse impacts, including loss of ecosystem services (see C.9.4)—of crop production activities may accrue differentially to women. Gender analyses, where not required separately, should be integrated into the ESIA process. ESIAs should also specifically consider the potential for such differentiation with respect to children and other vulnerable groups.

Note: *For key concepts and best practices for gender integration in crop production programming, see Global Food Security Strategy Technical Guidance: Advancing Gender Equality and Female Empowerment.*

Predicate Assistance on Keeping Children in School and Monitor. A condition of assistance to cooperative and individual producers should be that children may not provide agricultural labor during school hours. As noted in D.7, support to individual enterprises and actors should be conditional on correction of identified EHS and food safety deficits. This includes prohibition on underage labor. All such conditions must be monitored for compliance.

On the incentive side, cooperatives can be structured, for example, to pay or subsidize school fees (up to a set level per member) out of collective profits.

Note: *For key concepts and best practices for youth integration in crop production programming, see* Global Food Security Strategy Technical Guidance for Youth.

D.9.2 MITIGATION OF POTENTIAL ADVERSE IMPACTS ON CULTURAL SITES

Identify Cultural Sites in the Design Stage. Sites and landscape features of historic, religious/sacred, or other cultural significance in an intervention area should always be identified in the design/site selection stage. This can usually only be achieved reliably via actual site visits and community consultation, including with minority and indigenous members.

Design for Avoidance and Monitor Indirect Impacts. Design and site selection should avoid culturally significant sites and landscape features. Where this is not possible, many host countries have specific legal requirements that apply when projects may impact sites of cultural significance; these requirements must be met and, at minimum, a mitigation approach informed by appropriate consultations must be developed and implemented.

D.9.3 MITIGATING THE IMPACTS OF INSECURE LAND TENURE

Understand Local Land Tenure and Land Uses. Understanding (1) local land tenure, including the relative security or insecurity experienced by women and members of disadvantaged groups; and (2) use of land in a project intervention area, including for provisioning services (C.9.4), is essential to determining whether the impacts of insecure tenure (see C.9.3) may be a concern in the context of crop production activities.

Incorporate a Project Component to Strengthen Land Tenure, where Indicated. Where such impacts are of concern, integrating a land tenure reform/strengthening component is the primary mitigation. This may range from supporting smallholders in obtaining formal title, to support for community or district-level cadastre schemes, to formalizing informal usage rights.

Strengthening insecure land tenure does not by itself guarantee increases in agricultural productivity or access to capital, particularly in the short run, but it is an essential component of a strategy to raise productivity in the long term (Boudreaux & Sacks, 2009)—and may significantly increase the probability and intensity of conservation efforts by smallholders. Examples of these linkages are provided in Figure 5, below.

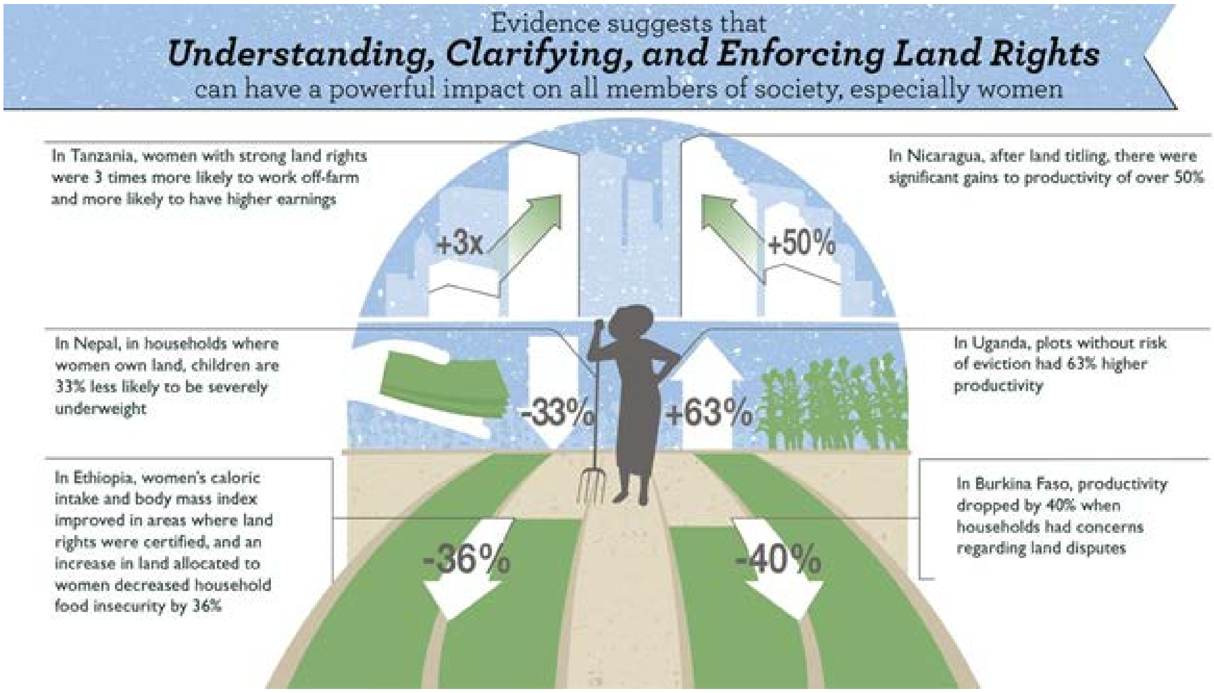


Figure 16. Linkages between Land Tenure and Economic and Nutritional Benefits of Crop Production

Source: https://www.usaid.gov/sites/default/files/documents/1865/USAID_Land_Tenure_Infographic_October-2016b.pdf

D.9.4 MITIGATING IMPACTS FROM LOSS OF ECOSYSTEM SERVICES AND APPROPRIATION OF NATURAL RESOURCES

Use an Ecosystem Services Frame in ESIA process. To identify the potential loss, restriction or inequitable access to ecosystem services from crop production activities and the resulting social impacts, pre-implementation ESIAs should incorporate an ecosystem services "frame" or perspective; see USAID's Environmental Compliance Factsheet: Ecosystem Services in Environmental Impact Assessment.

Design and Mitigate to Prevent Loss of Ecosystem Services. Ecosystem services and the social benefits they provide are typically difficult to replace. Thus, where impacts derive from the *loss* of ecosystem services, the primary mitigation strategy is to prevent the loss of these services. Mitigation approaches to preserve land, landscape and biodiversity, control pollution, manage water resources, and sustain soil health are presented in D.1.

Address Land Tenure, Gender and Vulnerable Groups Issues as Indicated. Where impacts derive from restriction or inequitable access to ecosystem services, this is frequently because of inequitable and insecure land tenure, and/or because of disadvantages that women and other groups face in access to resources. See D.9.1 and D.9.2 for indicated mitigation.

Consider a Community Based Natural Resource Management (CBNRM) Approach. In CBNRM, communities become responsible for managing natural resources (e.g. forests, land, water, biodiversity) within a designated area. Advocates of CBNRM see it as a means for improving socio-economic conditions and participation of marginalized groups.

> ***Note:*** *CBNRM requires careful, expert design and implementation, and key conditions to succeed.*

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- Strategy Objective 1: Inclusive and Sustainable Agricultural-Led Economic Growth
- Strategy Objective 2: Strengthened Resilience among people and systems
- Strategy Objective 3: A well-nourished population, especially among women and children
- Policy Programming
- Gender Equality and Female Empowerment
- Capacity Development
- Employment and Entrepreneurship
- Towards Digitally Enabled Global Agriculture and Food Systems
- Finance: Unlocking Capital Flows
- Increased Sustainable Agricultural Productivity
- Diversifying Livelihoods, Resilience, and Pathways Out of Poverty
- Investing in Livestock Production and Animal Source Food Market Systems
- Market Systems and Value Chain Programming
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ANNEX 1: IRRIGATION

1.1. BRIEF DESCRIPTION OF SECTOR

Irrigation is a broad term referring to any means of delivering supplemental water for crop production. In areas where traditional rain-fed agriculture has a high risk of crop failure, irrigation helps ensure more stable production by addressing crop water shortfalls at critical growth stages. Irrigation systems can rely on either natural water sources such as rivers, lakes, streams, groundwater aquifers, floodplains, floodways, wetlands, or on constructed infrastructure such as dams, levees, dikes, canals, wells, ponds, reservoirs and boreholes (Sustainable Water Management Wiki, n.d.). Water infrastructure is addressed by the Construction and Water and Sanitation SEGs.

Worldwide, irrigated agriculture accounts for about four-fifths of global water withdrawals. Irrigation and drainage continue to be an important source of productivity growth, especially in Sub-Saharan Africa and parts of Latin America that still have large untapped water resources for agriculture. Where rainfall is less scarce, as in many equatorial countries, irrigation is used for off-season cropping, for rice cultivation, or to produce high-value crops like vegetables (Ward et al., 2011).

BOX 7. IRRIGATION SYSTEMS

The three broad classes of irrigation systems are: 1) pressurized distribution; 2) gravity flow distribution; and 3) drainage flow distribution. Pressurized systems such as sprinklers, center pivot, drip and trickle all rely on pressurized pipe networks to distribute water, and therefore include pumps. Gravity flow systems move and distribute water at the field level through ditches and pipes that are not pressurized, relying on gravity to move water down slope. Less common is drainage flow irrigation (or sub-irrigation) where sub-surface drainage water is controlled at critical points to raise the level of groundwater to reach crop plant roots.

A number of factors must be considered in the selection of an irrigation system. These will vary from location to location, crop to crop, year to year, and farmer to farmer; however, these considerations include the compatibility of the system with other farm operations, economic feasibility, topographic and soil properties, water quality and availability, crop characteristics, and social constraints.

Adapted from: FAO, "The Practice of Irrigation" http://www.fao.org/3/T0231e/T0231e03.htm.

In development contexts, irrigation projects are often categorized as either large scale or small-scale, with risk and potential impacts scaling accordingly. However, the threshold between the two varies significantly with context: 50 Ha in one context may be small-scale, whereas 50 Ha in the context of a small island community or sensitive ecosystem may be large. Gravity-flow systems are the most common in developing areas, although sprinkler systems are used on larger commercial farms in Zimbabwe, South Africa, Kenya, Zambia, various countries in North Africa, China, India, and Mongolia. Expansion of other irrigation systems such as trickle, drip, or treadle pumps has been slow.

Irrigation is likely to gain importance as a climate change adaptation technique. Farmers may adopt irrigation as a response to temperature increases, more variable precipitation patterns, and more extreme events, such as droughts, associated with climate change.

There are many obstacles to increased irrigation in developing countries including limited and diminishing freshwater resources. In a number of areas where water is scarce, coordinated planning is not possible due to the absence of any regional agreement on the use of water resources and infrastructure. Even where water resources are available and adequate, other conditions may hinder irrigation development. These include unfavorable topography and soils; distant markets; inadequate infrastructure, lack of training and management skills; no access to finance and credit or lack of extension services. Moreover, the many adverse environmental impacts associated with irrigation (see next section) should encourage careful programmatic planning and design.

1.2. POTENTIAL ENVIRONMENTAL IMPACTS OF IRRIGATION

Irrigation has an extensive set of potential, significant adverse environmental and social impacts, including but not limited to: soil quality, quantity and quality of water, natural and social conditions of the watershed and conditions downstream of the irrigation schemes. Impacts tend to be greatest in the case of new schemes. However, modifications to existing irrigation projects may also generate new, unanticipated impacts.

For these reasons, all irrigation development or rehabilitation projects should undergo pre-implementation environmental and social impact assessment. Note that it often takes time to accurately predict the economic, social and environmental impacts that new irrigation schemes will have on the area, and although any given irrigation project may be small, the cumulative impact of many small irrigation projects can be significant.

> ***Note:*** *USAID's environmental procedures identify "Irrigation or water management projects, including dams and impoundments" as a class of actions normally having a significant [adverse] effect on the environment (22 CFR 216.2(d)). Under the procedures, such actions usually require a full ESIA study (a USAID Environmental Assessment) in conformity with 22 CFR 216.6.*

1.2.1 MISMANAGEMENT OF WATER RESOURCES

Water mismanagement leads to loss of valuable water. As a result of poor irrigation system design, poor water management and poor irrigation site choice (e.g., sloping lands that increase runoff) scarce water resources may be used inefficiently. There may be significant loss via leakage and evaporation from canals and storage dams, as well as poor water management by farmers within the scheme; these problems are particularly acute under arid or semiarid conditions. Poorly maintained canals result in water losses and the growth of vegetation in the canals, with noticeable effects on efficiency, distribution and leakage.

1.2.2 WATER CHANGES

Surface Water Sedimentation. Because irrigated land is already wet, it may be less able to absorb rainfall. Runoff from irrigated croplands during a storm can thus be heavier than runoff from un-irrigated areas, carrying sediment and farm chemicals into water bodies. The effects of sedimentation on rivers are compounded by any changes in flow regimes caused by irrigation structures. Increased sedimentation upstream can also clog irrigation intakes, pumps, filtration operations, and in-field channels downstream.

Water Distribution. Poor irrigation distribution uniformity can negatively impact crop yields. Lack of irrigation system maintenance, poor water quality, inadequate filtration, poor, or inefficient system operation, can all lead to decreases in distribution uniformity. Poor design, construction and placement of water inlet points for irrigation can all erode the soil at the head of an irrigated field. The eroded soil may accumulate in the middle or at the ends of the field where the water moves more slowly, interfering with in-field water distribution.

Water Pollution from Runoff or Direct Disposal of Pesticides and Other Toxic Substances:

- As discussed in C.4.3, pesticides can endanger human and animal health, persist in nature, and interfere with natural pest controls (such as predatory insects). As compared to non-irrigated crop production, the use of pesticides in the context of irrigation often presents heightened risks of surface or groundwater pollution.

- Use of sewage or wastewater for irrigation can spread disease and contaminate soils and food with heavy metals, which can have toxic effects on ecosystems and human health. Also, if human excreta is used as fertilizer or deposited in irrigated fields, rainwater runoff may transport them into open water bodies where they may spread diseases such as cholera, hepatitis and parasites.

- Commercial irrigated farming projects normally use commercial fertilizers, which when overused, lead to excess nutrients in the ecosystem. Nitrates, which are water-soluble, are quickly transported into rivers and estuaries. As phosphate concentrations rise in surface waters, they may stimulate rapid growth of aquatic vegetation and algae. Excess nitrates in water sources can be toxic to aquatic life and young children.

  Loading water bodies with nutrients encourages algal blooms, which deplete life-giving dissolved oxygen and harm aquatic life and fisheries. These conditions are most severe in shallow and slow-moving water bodies, such as reservoirs and low-flow regime rivers. Reservoirs may also become anaerobic (i.e., lacking oxygen) near the bottom due to decaying organic matter. When organic matter decomposes under these anaerobic conditions, the process yields hydrogen sulfide, methane and ammonia, all of which are poisonous to humans and aquatic organisms and are also potent GHG. Because irrigation can affect downstream water quantity, it can also affect water quality by reducing the amount of water available to dilute contaminants.

Groundwater Pollution. Irrigated agriculture can cause groundwater pollution. The magnitude of groundwater pollution associated with irrigated agriculture is dependent on a variety of factors, such as chemicals/materials applied to the land/crops, soil/aquifer characteristics, and water management.

Altered hydrology. Diverting water for irrigation affects watersheds by altering rivers' flow regimes (patterns of flow volume) and affecting the depth of the water table. Without irrigation, rivers may experience large seasonal variations, flooding during the rainy season (flood regime) and carrying small water volumes during dry seasons (low-flow regime). These impacts are discussed further below:

- **Altered Flow Regimes.** Irrigation takes water from the already limited supply available during low-flow regimes. This may leave too little water for downstream uses such as drinking water, hydropower, transportation, and other irrigation projects. In addition, reduced water quantity often translates into reduced water quality, because there may not be enough water to dilute pollutants to acceptable limits. Turbidity also increases as flows are diminished. If the river is linked to wetlands or an estuary, reduction in water volume or quality may harm critical animal habitats, fisheries, and flora as well as drinking water supplies.

- **Altered Flood Regimes**. Irrigation reduces river flooding, which may be helpful in that it lessens the potential for property damage and loss of life. On the other hand, irrigation also alters natural irrigation and fertilization of flood plains, disrupting traditional agricultural practices. Fisheries and aquaculture projects in estuaries and coastal areas may be harmed by reduced floodwaters. Diverting floodwaters leaves less water to recharge groundwater supplies and wetlands. Furthermore, floods are important for transporting sediment downstream. When they are reduced, the decrease in flow may contribute to greater siltation upstream, making rivers less navigable.
- **Altered Water Table.** Lowering the volume of water in rivers has a similar effect on groundwater levels. Less river water means less groundwater recharge and lower water tables. This may make springs and wells dry up, leaving people to collect water from more distant sources, or it may make water less potable, possibly increasing the risk from diseases such as guinea worm, schistosomiasis, dysentery and typhoid. Long-term reductions in water table levels can lead to land subsidence (slumping). Irrigation can also cause increased groundwater recharge from the unavoidable deep percolation losses occurring in the irrigation scheme
- **Groundwater-related Land Subsidence.** Groundwater-related subsidence is the subsidence (or the sinking) of land resulting from groundwater extraction. It is a growing problem in the developing world as cities increase in population and water use, without adequate pumping regulation and enforcement. One estimate associates 80 percent of serious land subsidence problems with the excessive extraction of groundwater, highlighting the importance of this issue (Perlman, 2017).

1.2.3 SOIL CHANGES

Irrigation water quality may adversely affect soils, plants, and irrigation equipment. All irrigation water contains dissolved mineral salts; the concentration and composition are determined by the particular water resource used. Excess salt can reduce crop yields and decrease water infiltration in soils while too little salt can result in a chemically compacted soil.

Salinization. Intensified agricultural production on irrigated lands can reduce soil fertility over time by making it more saline. A high level of salt in the soil limits what crops can be grown, reduces crop germination and yields, and may make soils more difficult to work. Excessively saline soils force farmers to abandon fields. Salts accumulate in soils in three main ways:

- Irrigation water contains salts. Irrigation water is taken up by plants or evaporates into the atmosphere, but salts accumulate in the soil. Flatter, low-lying areas; water tables with a low hydraulic gradient; or low-permeability soils are the most susceptible. Depending on upstream conditions, the water source itself may become more saline over time, increasing the salinization rate of the soil. Also, systems that reuse drainage water (e.g., runoff) may contribute to salinization. Artificial and natural fertilizers may not be fully absorbed by plants, leaving salts to accumulate in the soil.

- Salts may occur naturally in the soil and adding extra water through irrigation mobilizes them. This problem is often severe in desert or arid regions where natural rainfall is inadequate to remove the salts from the root zone by leaching.
- If the water table is high, water will rise through capillary action and evaporate, leaving salt in the upper layers and on the surface of the soil. Excess irrigation can also raise the water table and is often associated with salinized arid regions, where large areas of once-arable land have become unusable.

Excessive salt can cause irreversible damage to the soil structure, particularly in clay soils. In areas with acid sulfate soils, such as tropical coastal mangrove swamps, irrigation removes cations (positively charged ions) from the soil and reduces the availability of nutrients to plants. As an acid sulfate soil dries out, the change in pH (acidity) also decreases the organic content and may release elements that can have toxic effects on the ecosystem.

On islands and in coastal areas, saline intrusion into groundwater sources is a major problem associated with drawing water for irrigation and drinking water. If too much groundwater is drawn, salt water can enter the aquifer. This may have a major impact on other aquifer users, and on the entire coastal ecosystem, particularly plants and fisheries.

Alkalinization or Acidification of Soil. Fertigation (injection of fertilizers into an irrigation system) with nitrogenous fertilizers can contribute to soil acidification. Alkaline irrigation waters may cause or increase soil alkalinity.

Waterlogging is associated with excessive irrigation on poorly drained soils. As is common for salinization, it occurs in poorly drained soils where water can't penetrate deeply, for example, where there may be an impermeable clay layer below the soil. It also occurs on areas that are poorly drained topographically. The irrigation water (and/or seepage from canals) eventually raises the water table in the ground – the upper level of the groundwater – from beneath. Because soil water tests are expensive, growers do not generally realize that waterlogging is happening until it is too late. The raised water table results in the soils becoming waterlogged. When soils are water logged, air spaces in the soil are filled with water, and plant roots essentially suffocate for lack of oxygen. Waterlogging also damages soil structure (Muir, 2014).

1.2.4 IMPACT ON AIR

In irrigated agricultural areas, one of the main causes of air pollution and GHG emissions is the use of energy for operating irrigation pumps. Pumping activities in the irrigation sector are energy-intensive and use mostly polluting fossil fuels.

1.2.5 IMPACTS RELATED TO CONSTRUCTING IRRIGATION INFRASTRUCTURE

Constructing irrigation infrastructure such as dams, reservoirs, canals, wells, and boreholes can have adverse impacts on the environment. As explained by International Rivers (n.d.), "The environmental consequences of large dams are numerous and varied, and includes direct impacts to the biological, chemical and physical properties of rivers and riparian (or "stream-side") environments." All water infrastructure construction requires environmental screening. Further information about water infrastructure can be found in the Construction and Water and Sanitation SEGs.

1.2.6 IMPACTS ON HUMAN HEALTH

Irrigated agriculture can improve human health through greater food security, better nutrition, improved local infrastructure, and higher incomes that allow access to medicines and health services. However, irrigation may also support vectors of waterborne diseases in both humans and animals, including malaria, schistosomiasis, dengue, bancroftian and lymphatic filariasis, river blindness, loiasis, roundworm, tapeworm, guinea worm, yellow fever, sleeping sickness, cholera, typhoid, hepatitis, and leishmaniasis that breed in stagnant water.

For example, stagnant or low-flow water bodies such as clogged irrigation canals or waterlogged fields and rivers under extremely low-flow regimes can breed malaria-carrying mosquitoes and the snails that transmit schistosomiasis. Lowered water tables in arid regions can increase the incidence of sandflies, which transmit leishmaniasis. Using polluted wastewater for irrigation can spread roundworms and tapeworms in both livestock and humans. Finally, pollutants, including pesticide residues, excess nutrients from fertilizers, and saltwater intrusions in groundwater, all threaten drinking water sources, leading to increased sickness and even death.

Groundwater pumping for irrigation can increase arsenic levels in irrigation and drinking water (Stanford University, 2018). See [USAID Africa Bureau Water Quality Assurance Plan (WQAP)].

1.2.7 IMPACTS ON ECOSYSTEMS

Diverting water for irrigation leaves less water for downstream ecosystems, including wetlands, mangroves, and coastal estuaries. Discharge water from irrigated fields may contain more salt, less dissolved oxygen, more pollutants, and a heavier silt load than the incoming flow. It also tends to be warmer than receiving rivers and streams. Irrigation runoff reaching these ecosystems can encourage algal growth and harm fish and bird populations that rely on fish for food, among other changes to ecosystem composition.

Less water flowing downstream to wetlands hampers their natural water treatment functions. A long-term reduction in water flow to wetlands will cause them to shrink and alter the composition of wetland vegetation. These changes in flora cause loss of animal habitat, flood protection, and coastal erosion buffers. Mangroves, in particular, require large volumes of fresh water and sediment to protect coastal areas and to support commercially valuable spawning grounds. Decreases in water flow also slow recharging of local groundwater.

Increased erosion and consequent siltation of water bodies damages fisheries and aquaculture. Land clearing for irrigated agriculture, particularly for monoculture crops, may destroy sensitive and important animal and plant habitats. Wetlands are often deliberately drained and used as sites for irrigated agriculture because of their high soil fertility, but while the fertility is often short-lived, the wetlands' environmental benefits are lost permanently. Larger areas of irrigated monoculture are especially prone to crop pests and diseases. All of these impacts may harm local species that use wetland habitats, as well as migratory bird populations.

1.2.8 SOCIAL IMPACTS

Although irrigation is usually introduced to improve economic conditions and support development, it may result in significant adverse social and economic impacts. Most irrigated agriculture systems create opportunities for both cohesion and conflict. Conflicts over water can range from household level to major conflicts within and between communities that disrupt food supply and security that irrigation aims to support.

New irrigation schemes can disrupt communal land use rights and highlight discontinuities between traditional and legal land rights. Individual water rights, often separate from land rights, may need to be negotiated, particularly for small plots. Changes to field layouts may be necessary and some cultivated land may be lost, which will require adequate compensation. Even successful irrigation projects can harm downstream users by reducing water volumes and/or quality.

Moreover, successful irrigation projects tend to result in induced settlement and in-migration. Disrupted communities and displaced settlers may be more likely to exhibit behavior that puts them at high risk for HIV/AIDS. In addition, if growth is unplanned, the community may be without adequate provision for potable water supply, waste disposal, housing, roads, or other services. Public health in settlements can actually worsen as a result of an irrigation project. Larger, denser populations in a newly irrigated area undertake related activities with environmental impacts of their own, such as more agriculture, grazing, and harvesting of forest products. This phenomenon, called the Hinterland Effect, should be anticipated and planned for before beginning any irrigation project.

Irrigation generally benefits landowners more than tenants or communal land users. While women and children may benefit from higher income and improved nutrition, they may also lose access to lands traditionally used to collect fuel wood or grow vegetables. Also, irrigation projects may involve pastoralists with little or no experience with irrigation farming techniques. They are less likely to benefit from such projects than are outside investors or entrepreneurs who hire the workers as tenant farmers.

Use of water for irrigation increases water scarcity and subsequently has impacts on water prices and its opportunity costs.

1.3 PROJECT DESIGN AND MITIGATION

Complete success in irrigation development is challenging. Planning for both large-scale and small-scale irrigation projects should consider potential technical, environmental, social, economic, and ecological factors; take local, national and regional experience in the sector into account; and involving knowledgeable local staff.

As noted in 1.2, all irrigation development or rehabilitation projects should undergo pre-implementation environmental and social impact assessment (ESIA); this is required by host country law or regulation in almost all cases; see note at 1.2 regarding requirements under USAID's environmental procedures.

Mitigation design follows from the impacts identified in and is part of the ESIA process. Feasible mitigations depend in part on whether the project is designing a new irrigation system, rehabilitating an existing one, or supporting ongoing irrigated activities.

When developing a new irrigation project, it is often advisable to start with a smaller pilot area for irrigation, using conservative estimates of water availability. As more data about low-flow conditions become available, the irrigated area can be expanded to match the water supply.

1.3.1 IRRIGATION SYSTEM ENVIRONMENTALLY SOUND DESIGN AND CONSTRUCTION

Irrigation system design must simultaneously consider several fundamental scheme parameters in order to design effective and efficient irrigation systems or improve and resolve existing systems. Note that the average precipitation during the growing season is not a good determinant of irrigation needs. Other factors to consider include the timing and amounts of rainfall during the season, the soil's ability to hold water and the crop's water requirements.

Prior to selecting irrigation methods, it is important to identify soil properties, including soil texture, structure, depth, permeability and infiltration, salinity, and pH. It is also important to understand the topography and size of the field, irrigation water availability, and quality and type of plants to be grown. The system should control where, when and how much water is supplied to promote yield and enhance the economic efficiency of crop production. Watering requirements, both volumes and frequencies, will change based on time-variable crop needs. System design should aim for optimal growing conditions in a specific plot or season while protecting the fields against long-term degradation.

In summary, considerations for choice of irrigation sources, types and methods should include:

- Soil types in the area;
- Capacity of land and topography of the area to be irrigated;
- Optimum scale of the scheme;
- Water resources - both quantity and quality to support irrigation;
- Climate of the area and seasonal water availability;
- Crops appropriate to soil type;
- Social factors such as water use conflicts and migration changes that may impact local health and increase demand for housing, health, education and other services;
- Community's role in managing the system;
- Economic factors such as sources of extension information, technology and input supply for the scheme (e.g., tools, seeds, machinery); Output markets for increased production;
- Labor availability;
- Local traditional methods and skills and farmers' experience with irrigation farming techniques; and
- Ecological considerations.

Constructing irrigation works involves a set of construction-related environmental concerns, including worker sanitation, location and management of borrow pits, construction of access roads, etc. See the SEGs on Construction, Roads, and Water and Sanitation.

1.3.2 IRRIGATION MANAGEMENT

Irrigation management focuses on management of the irrigation system and processes. Irrigation management includes the following:

- Maintenance of irrigation and drainage operation;

- Ensuring that operations match demand for irrigated amounts and timing;
- Monitoring and enforcing water quality standards;
- Defining and enforcing water abstraction;
- Managing irrigation and drainage to prevent pollution and spread of disease; and
- Defining and enforcing ecological requirements.

Precipitation Measurement. Good irrigation management begins with an accurate measurement of the amount of rain received on each irrigated field. Ideally, each irrigated field should have at least one and possibly two rain gauges (at least two inches in diameter) mounted on posts next to the field. It is very important to install water-level gauges to collect data during regular and dry conditions. This information will assist with the planning of irrigated fields and new crops, and the need for maintenance or new infrastructure. This information is also needed for water use planning and agreements among farmers and communities over water use and distribution. Local personnel should be trained to use stations or gauges to record measurements.

Soil Moisture Management. The estimation of soil moisture is the most common method of irrigation water management. However, it must be done on a regular basis throughout the growing season. During the dry season, checking the soil moisture two to three times each week may be necessary. Mechanical devices such as tensiometers and soil moisture blocks can also be used for irrigation water management. These devices are particularly helpful with fruit and vegetable crops. For these crops, they have proven to be accurate, reliable and relatively inexpensive.

Irrigation scheduling is deciding when to turn on the irrigation system and how much water to apply. Irrigation scheduling is the science of applying the proper amount of water at the proper time to provide the maximum usable soil moisture in a plant's root zone without causing harmful stress. Irrigation scheduling is a balancing act between applying too much water or not enough to meet plant needs at a particular stage of growth.

Water Quality Management. Low-quality water is defined as water with a relatively high content of impurities, among which salts are the most important factor. Such water can be used for irrigation of several horticultural crops. Use of poor quality waters requires three changes from standard irrigation practices: (1) selection of appropriately salt-tolerant crops; (2) improvements in water management, and in some cases, the adoption of advanced irrigation technology; and (3) maintenance of soil-physical properties to assure soil tilth and adequate soil permeability to meet crop water and leaching requirements. Low-quality irrigation water should not be used on clay-rich soils, but might be used on more permeable sandy soils where pollutants will not accumulate and where the water table is deep enough to avoid the possibility of pollution of the subsurface water table (Oster, 1994). The presence of organic and inorganic solids that may be suspended or dissolved or a combination of both may require installation of a water filtration system. Where water is used as potable water, USAID generally requires a Water Quality Assurance Plan (WQAP).

Water Conservation. According to the International Water Management Institute, agriculture accounts for about 70 percent of global water withdrawals and is constantly competing with domestic, industrial and environmental uses for a scarce water supply. Population growth and growth of competing industries, including food processing, put further pressure on water resources. Long-term availability of water for agriculture can be impacted by temperature increases, variability of precipitation patterns, and occurrence of extreme events, such as floods and droughts. Historical patterns of climatic conditions, such as temperature and rainfall, as well as future projections as a result of climate change should inform discussions of water availability. If such information is not available, project designers should consider making the investments necessary to obtain it.

Concerns regarding projected water scarcity place further emphasis on the need for efficient methods of water management. Increasing scarcity and competition also raises the issue of water rights and the real price of water. Not only efficiency, but also fundamental issues of equity need to be considered in water allocation or reallocation.

Methods of water conservation may include rainwater harvesting, including lined water ponds; underground water storage; drip irrigation; irrigation schedules; drought tolerant crops; soil moisture conservation methods(see below); rainfed agriculture; compost and mulch; cover crops; and conservation tillage. Incorporating traditional soil and water management experiences from systems such as zai, *dambos* in Africa, *taanka* and Khadin in India and other methods, as appropriate, into modern water management should be considered. See section D.1.5 in the main text.

1.3.3 MANAGEMENT OF SOIL UNDER IRRIGATION

An understanding of soil moisture is essential to efficiently manage irrigation systems. As stated above, the objective of irrigation management is to maintain the amount of moisture in the soil between field capacity and the minimal allowable water balance to satisfy plant requirements. See Section A.4.5 in the main text. Soil health is closely related to the chemical characteristics, quantity and timing of the irrigation water; see 1.2.3 above.

1.3.4 IRRIGATION SYSTEM MAINTENANCE

Maintaining irrigation systems is one of most effective ways to reduce wasted water, reduce pollution from runoff and over-irrigation, and improve plant health by applying the correct amount of water where it can be utilized. Irrigation maintenance must troubleshoot problems and maintain components to keep the system working reliably and cost effectively. Availability of spare parts must be ensured to justify investment in design of irrigation systems.

To reduce GHG emissions, energy costs, and fuel pollution, pumping systems should be maintained. Solar-powered pumps are available but the main barriers to the wider use of solar pumps are their higher capital costs and general lack of familiarity with this technology.

All components of an irrigation system require the availability of spare parts. Regular maintenance will be necessary to keep irrigation canals free of weeds, oils, and trash, reduce the effects of sedimentation, and prevent wasteful leaks. Farmers and communities should devise and implement a workable approach to operation and maintenance before any irrigation program is undertaken. System design should include responsibilities for maintenance, monitoring, and regular operations. To prevent anaerobic conditions in reservoirs, organic matter like trees should be cleared away before filling. Further, multilevel dam outlets help ensure that downstream waters are sufficiently oxygenated.

1.3.5 CAPACITY BUILDING FOR IRRIGATION MANAGEMENT

The need to better manage overall water resources and to facilitate the allocation of water among all users requires an expansion of national integrated planning. It must be recognized that each country and region has its specific characteristics, institutional frameworks, and requirements with respect to water resources and therefore, operational strategies for water sector capacity building must be tailored for each situation. Such strategies' main objectives should be to improve the quality of decision making, sector efficiency, and managerial performance in the planning and implementation of water sector programs and projects (Hamdy & Lacirignola, 1997).

1.3.6 PREVENTING POLLUTION AND SPREAD OF DISEASE BY IRRIGATION ACTIVITIES

Pollution Control. A combination of measures must be undertaken to protect surface and groundwater from runoff and leaching of irrigation water that is polluted with agricultural chemicals and is rich in nutrients. Both structural and management practices are available for managing water and chemical inputs more efficiently and controlling runoff and leaching to minimize water pollution. These measures include efficient irrigation water management, integrated pest management, comprehensive nutrient management, animal waste management, conservation agriculture, and, where sewage waste is used, sewage waste pretreatments (Wubetu, 2016). See Section D.1.3 in the main text.

Vector Control. As a rule of thumb, any water source that stands for more than five days can become a source of disease vectors. Physically manipulating the amount of standing water that occurs on agricultural lands reduces the need for biological controls and chemical insecticides. Undertaking measures such as using drainage; scheduling irrigation; using drip and sprinkler irrigation rather than flooding fields; covering tanks that contain standing water; reducing seepage, and other measures that reduce the amount of standing water, will reduce populations of disease carrying insects (Vector Disease Control International, n.d.).

Education and awareness building about the importance of water quality, prevention of water pollution, and control of disease vectors should be considered for integration into programs supporting irrigation activities.

1.3.7 ECOLOGICAL CONSIDERATIONS

Reservoirs and irrigation canals can also be used for aquaculture and as bird habitats. Aquaculture in canals can help to control weeds while providing a source of protein and income. Bird sanctuaries and wildlife parks can be established around reservoirs to protect wildlife and stabilize shorelines against overuse and erosion.

To protect the water source while designing new irrigation systems or rehabilitating old systems, communities should be encouraged to conserve natural areas surrounding the upstream watershed. This conservation zone or source water protection area will ensure supplies of quality water in the future via increased filtration and pollution control. This type of protection maximizes the fresh water provisioning service of the ecosystem, water regulation, and waste purification ecosystem services. If this conservation area is effectively protected, secondary ecosystem services—including local climate regulation, food and fiber provisioning services— may also be secured.

1.3.8 COMMUNITY PARTICIPATION

Community and farmer participation in planning and designing irrigation schemes (or rehabilitating existing ones) is critical to minimizing adverse socioeconomic impacts and maximizing community benefits. Construction of new dams and irrigation projects can become a source of risks of displacement and risks to land tenure, employment, historic heritage and community structures. Therefore, an assessment of potential impacts on populations and stakeholder participation is an essential component in design of medium and large irrigation schemes.

Community participation, defined as engaging water users in the decision-making processes for the planning and implementation of irrigation projects, is critical for the sustainability of irrigation schemes. Water User Associations (WUAs) can enhance community participation in irrigation projects. A WUA is an organization for water management made up of a group of small and large-scale water users, such as irrigators, who pool their financial, technical, material, and human resources for operation and maintenance of a local water system, such as a river or water basin. The WUA is usually run out of a non-profit structure and membership is typically based on contracts and/or agreements between the members and the WUA.

WUAs play a key role in integrated approaches to water management that seek to establish a decentralized, participatory, multi-sectoral and multi-disciplinary governance structure (ClimateTechWiki, n.d.). Developing WUAs requires a good understanding of community dynamics, and institutional, policy, legal, regulatory and customary structures of land and water rights issues. Establishing WUA committees must reflect the interests and inputs of the irrigation scheme users (Yami, 2013).