United Nations
World Food Programme

Climate Change in West Africa

Recommendations for Adaptation and Mitigation

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in the City of New York

WFP

Prepared for:
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Executive Summary

This report was drafted, at the request of the United Nations World Food Programme West Africa Bureau (WFP), at Columbia University's School of International and Public Affairs Program on Environmental Science and Policy. The report provides information on the impacts of global climate change on livelihoods and food security, as well as recommendations for the WFP to inform their adoption of adaptation and mitigation strategies. The program recommendations are organized according to vulnerability categories that the United Nations Environment Program (UNEP) has designated as being quite relevant for climate change: flooding, drought and desertification, deforestation, and direct impacts on food security.

The WFP in West Africa provides aid to a region of uniquely high vulnerability and variability. Political challenges, socio-cultural diversity and extreme poverty in the region foster a state of intense susceptibility to crises. The variation in climates, land types, and resource availability has important implications for the scale at which projects should be developed. While the WFP has the logistical infrastructure to provide short-term critical food needs and humanitarian relief, long-term community-based development and training programs will be necessary in order for the WFP to address the impacts of climate change.

Many of the recommendations are based on successful adaptation programs that have been practiced throughout the world. These recommendations may provide useful tools for the WFP in promoting the adaptation and mitigation of climate change as it relates to their mission. Research efforts lead to the conclusion that programs should be designed on a local scale according to the unique characteristics of a community, and that long-term development efforts will be most effective for the work of the WFP.

The analytical focus of this report emerged based on the four vulnerability areas as identified by the UNEP. While recommendations are organized according to vulnerability category, a combination of programs and approaches from different categories will likely offer the most effective approaches. Some of these recommendations are already in practice in West Africa, but implementation of such recommendations on multiple fronts will better achieve adaptation to climate change. In addition, knowledge sharing between institutions, governments, and local communities presents a vital channel for climate change preparedness.

The first section of this report contains information on the links between the WFP, climate change, and food security. We outline the ways that food security may be worsened by climate change, how the WFP's work may be affected, and the connections to the natural environment. Following this is an overview of predicted climatic changes in West Africa, including specific information on the abovementioned vulnerability categories. The report contains a basic explanation of the Earth's climate system, as a basis for understanding the process of climate change. The following Issue Chapters of the report contain our program recommendations for the specific vulnerability categories identified, which include:

Flooding
- Flood Management Structures
- Sea Level Rise Strategies
- Aquaculture in Flood Plains

Drought and Desertification
- Weather Index Insurance for Reducing Farmer Risk
- Rain Gauges and Sowing Charts for Planning Crop Planting
- Strategies to Reduce Desertification
- Rainwater Storage
- Micro-Irrigation

Deforestation
- Tree Nurseries and Afforestation or Re forestation Projects
- Solar Cookers as a Substitute for Fuel wood and Charcoal Stoves
- Carbon Dioxide Emission-Reducing Projects for Carbon Credit Generation

Direct Impacts of Climate Change on Food Security
- Incorporation of Agricultural Biodiver sity through Cropping Methods
- Homestead Gardening for Resiliency and Nutrition
- Fertilizer Application

These sections provide an overview of the particular recommendation, an analysis of the challenges and implementation issues, considerations regarding the relevancy of the recommendation to the work of the WFP, and an example of successful implementation. These chapters are followed by a series of Applied Studies that illustrate hypothetical applications of several program recommendations within different parts of West Africa.

The challenges that the WFP faces in promoting food security and sustainable livelihoods in West Africa cannot be understated. The impacts of global climate change will intensify current challenges and further complicate the ability of the WFP to achieve its mission. We very much appreciate the opportunity to provide research support and references for further work to support the efforts of the WFP in promoting food security, despite current and future challenges associated with climate change.

Introduction

This report provides some of the information and ideas that the World Food Programme (WFP) may use to incorporate climate change adaptation and mitigation strategies into their activities. Adaptation refers to the preparations necessary to survive and maintain quality of life given the expected impacts of global climate change. Mitigation refers to efforts to reduce activities that enhance global warming, such as combustion of fossil fuels.

The necessity of actively adapting to global climate change and working to mitigate its effects has recently received institutional recognition. The Executive Director of the WFP, Josette Sheeran, has stated that the WFP should prioritize meeting the challenges of climate change in order to continue to fulfill their mission. Towards this end, she has advocated for sustainable development and structural adaptation through "building back better," in addition to strategies that can be carried out in the agricultural sector, in communication systems, through policy-making, and through a range of other mechanisms (Sheeran 2008).

Ban Ki-moon and the United Nations have also been vocal about prioritizing climate change on the world agenda. In an address on World Health Day in April 2008, the Secretary-General stated, "Climate change endangers the quality and availability of water and food, our fundamental determinants of nutrition and health. It is causing more frequent and more severe storms, heat waves, droughts and floods, while worsening the quality of our air.... Climate change is real, it is accelerating and it threatens all of us. We must respond with urgent action to stabilize the climate" (Ki-moon 2008).

Through research conducted by Columbia University's School of International and Public Affairs Program on Environmental Science and Policy regarding predictions of the future climate, conditions in West Africa, and strategies emerging around the world, program recommendations and Applied Studies to address climate change in the region were developed at the request of the WFP West Africa Bureau. The program recommendations are organized according to vulnerability categories that the United Nations Environment Program (UNEP) has designated as being quite relevant for climate change. These vulnerabilities include flooding, drought and desertification, deforestation, and direct impacts on food security

This approach was selected as a useful framework because time constraints did not allow a more comprehensive analytical approach, such as a country-level analysis. The scope of challenges and complexity within West Africa made it necessary to select particular foci. While program recommendations are associated with specific vulnerabilities, many of these program ideas are useful for managing the effects of multiple vulnerabilities. Transfer across vulnerability categories can be considered in WFP program design.

Many of the ideas we offer here have already proven successful in other regions or through work by other organizations within West Africa. In order to facilitate evaluation of our recommendations we have included information such as feasibility, implementation considerations, challenges, relevancy to WFP operations, scale, educational needs, and the ways that program ideas are linked to climate change and food security.

The first section of this report contains information on the links between the WFP, climate change, and food security. We outline the ways that food security may be influenced by climate change, how the WFP's work may be affected, and the connections to the natural environment. Following this is an overview of predicted climatic changes in West Africa, including specific information on the abovementioned vulnerability categories. Also included is a basic explanation of the Earth's climate system, as a basis for understanding the process of climate change.

The Issue Chapters which follow contain program recommendations for the specific vulnerability categories identified. These chapters are followed by a series of Applied Studies that illustrate hypothetical applications of several program recommendations in areas within West Africa. Additional information and program ideas can be found in the appendices.

Background

Food Security and Climate Change

Efforts to reduce extreme poverty and hunger are inextricably linked to climate. The people who are most vulnerable and lack secure sources of food depend on rainfed agriculture and water sources for their livelihoods. They live in the least developed countries where extreme weather events can be the most devastating to their health and well-being. The changes to climate that have been observed and predicted will lead to more extreme weather events, which will occur with increased frequency and severity.

Periodic droughts and floods have been long-standing obstacles to fighting poverty and hunger in developing counties. The impacts of climate change will only make this fight more difficult. Developing countries currently lack the capacity and resources to adapt to existing impacts, let alone those that are anticipated. Shifts in growing seasons, unpredictable rainfall fluctuations and increased temperatures associated with climate change increase the difficulty of both self-sufficient and larger-scale agriculture production, reducing local food security and amplifying the need for food aid.

The WFP and Climate Change

The mission of the WFP, to eradicate poverty and hunger, is being made increasingly more difficult by adverse changes in the capacity of local populations to be self-sufficient. Weather-related shocks raise the demand for food aid, decrease the local food production capacity and ultimately increase the international prices for commodities. Impacts from changes in climate are putting a strain on the ability of the WFP to meet its mission directives (Sheeran 2008). Transporting food aid may also become increasingly challenging as infrastructure is damaged by the elevated intensity of precipitation and flooding events predicted to occur as a result of climate change. Rising sea levels and changes in agricultural capacity caused by highly variable weather patterns may prompt large movements of populations, which may also increase the long-term need for food aid.

Supporting sustainable development programs that help secure local livelihoods as well as building capacity for communities to adapt to climate change is an important element of WFP operations. These efforts will help to moderate the effects of climate change on vulnerable communities and temper the increasing need for WFP food aid and relief. West Africa is home to many of the poorest countries in the world and the chronic threat to food security in the region is only expected to worsen.

According to the UN Human Development Index, 7 of the 10 lowest ranked countries are in the West Africa region (UNDP 2007). While the WFP has the logistical infrastructure to provide short-term critical food needs and humanitarian relief, it will likely be their community-based food assistance and training programs that provide the tools necessary for long-term adaptation and mitigation efforts to manage climate change in the developing countries of West Africa.

Ecology of the Region

In order to understand the connections between climate and livelihoods, knowledge about local climate zones is essential. The West African region receiving aid from the WFP spans 18 countries. Within these countries are six climate zones based on Köppen-Geiger climate classification. Some countries are homogenous while others fall within multiple zones. These climate zones and their corresponding land types include:

1. Humid: Typically, these regions have annual average precipitation of at least 60mm and an average temperature of 18°C. They are partly or fully forested. Annual precipitation exceeds water demand during two rainy seasons. Examples include the Guinea, Liberia, Sao Tome and Principe, Sierra Leone and southern Cameroon. Some of these regions are also affected by the tropical monsoon.

2. Moist Sub-humid: Typically, these regions are roughly comparable to the humid areas in terms of temperature, but have less than 60mm of precipitation. They are comprised of forest transition areas and mosaics. These areas have two rainy seasons. Examples include the central portions of the Central African Republic and Ghana, northern Cote d'Ivoire, southern Benin, Guinea and Guinea Bissau.

3. Dry Sub-humid: Typically, these regions are defined by having less precipitation than water lost through evapotranspiration, with average annual temperatures higher than 18°C. They have one rainy season and are mostly winter dry and summer wet. They are comprised of mostly woodlands. Examples include coastal Gambia, northern and central Cameroon and Benin, northern Ghana, southern Chad and Burkina Faso, and coastal Senegal.

4. Semi-arid: Typically, these regions receive less precipitation than dry sub-humid areas and are also winter dry and summer wet. They include mostly steppe (grasslands) and woodlands. Examples include central Burkina Faso and Senegal, northern Benin and Cameroon, and southern Niger.

5. Arid: Typically, these regions receive well below 60mm of precipitation and are mostly dry in both seasons. They contain mostly desert or semi-desert vegetation, in addition to some steppe. Examples include central parts of Niger, Mali and Chad, Cape Verde, northern Senegal and southern Mauritania.

6. Hyper-arid: Typically, these regions have the least precipitation, are dry in both seasons and are mostly desert. Examples include northern Chad, Mali, Mauritania and Niger.

(Kottek 2006; WMO, UNEP 2002)

Global Climate Change and West Africa

Regulating Properties of the Climate System

Global Climate

The sun produces massive amounts of energy, which drive the Earth's climate system. The majority of this incoming solar radiation is received at the equator, but the physical properties of heat energy cause it to diffuse throughout the globe. The climate system is driven by the movement of this heat energy, and the properties of the atmosphere, deep oceans, land surface, cryosphere (ice cover) and biota (living organisms). The Earth "wants" to maintain a radiation balance over time, emitting the same amount of energy into space that it receives from the sun. However, this process of coming to equilibrium would lead the Earth to be much too cold to sustain life. To keep Earth at a temperature higher than equilibrium, the greenhouse effect absorbs heat in the atmosphere. Human comfort, nutrition and health are all influenced by the global climate system. Biodiversity (the variety of organisms and habitat present in an ecosystem) and the wide array of cultural and social traditions on Earth are influenced by variations in climate between different regions. (Philander 1998)

Sources of Greenhouse Gases

Current changes in climate are partially caused by increasing emissions of greenhouse gases, which trap heat in the atmosphere. Carbon dioxide naturally cycles through the environment, but has dramatically increased in concentration due to human activities. The amount of carbon dioxide in the atmosphere has increased from a pre-industrial revolution value of 280ppm to 379ppm in 2005 (IPCC 2007). Some of the WFP's activities, such as transportation, contribute to increased carbon dioxide in the atmosphere. Refugees burning fuelwood in connection to deforestation activities is also a source of carbon dioxide emissions.

Methane, another greenhouse gas, has twenty-one times the heat absorption capacity of carbon dioxide, meaning that each molecule traps more heat inside the Earth's atmosphere (IPCC 2007). It comes from sources such as combustion of fossil fuel and livestock production. Additionally, rice fields have recently been discovered as large methane emitters (Neue 1993).

Regional Climate – West Africa

Recent advances in modeling, higher resolution, and further understanding of the physical processes of the climate system have made regional climate projections increasingly more reliable (Ward 2008). Most of the rain in West Africa falls between July and September (IPCC 2007). Rainfall variability is impacted by the regional climate, including local sea surface temperatures (SST) in the Gulf of Guinea, the West African monsoon, topography, and local land surface interactions (Zeng et al. 1999, Giannini et al. 2003, Cook and Vizy 2006). When the position of the rain belt shifts, there are large local changes of rainfall (Ward 2008). West Africa presents particular rainfall variability, partially connected to the West African monsoon.

El Nino Southern Oscillation (ENSO) has a significant influence on rainfall at interannual scales (IPCC 2007). It was originally thought that the explanation for the drought that has been occurring in the Sahel since the 1970s was primarliy due to land use changes. However in recent studies sea surface temperatures are considered to have a strong role in rainfall variability (Nicholson 2000; IPCC 2007; Giannini et. al. 2003).

Current Climate Projections

West Africa will face climate changes in the near future and over long-term timescales. Increasing global temperatures are resulting in different climate impacts across the West Africa region. The following are some of the leading projections of trends and scenarios for West Africa. These projections attempt to predict the "climate state" at a certain point in time. Long-term projections lack the ability to be verified due to the long time scale, as opposed to seasonal forecasts, which can be predicted with more certainty. With any projection there is a given level of uncertainty. However, they provide useful information for making decision for the future. These projections come from the latest Intergovernmental Panel on Climate Change Report (IPCC 2007) and leading climate experts who are conducting research in this region.

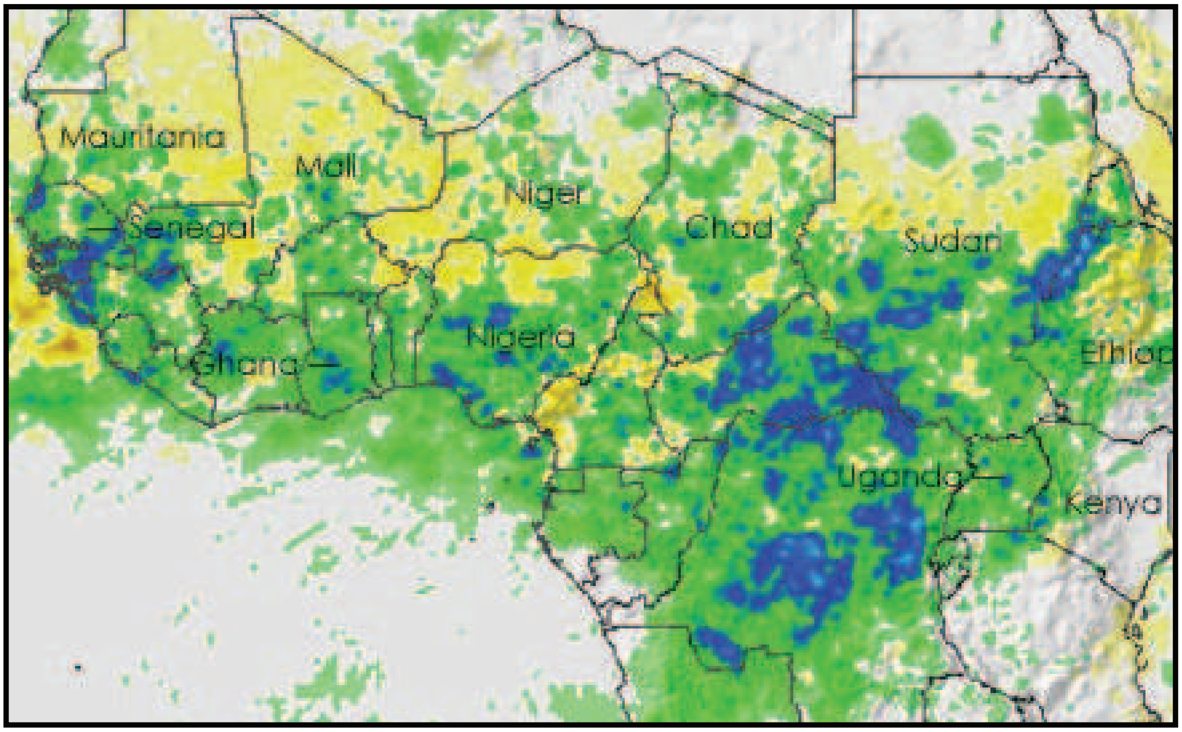
Short-term Predictions

- It is predicted the number of extremely dry and wet years will increase during the present century (IPCC 2007).
- It is still uncertain how rainfall will change over this century in the Sahel, along the Guinean Coast, and in the southern Sahara (IPCC 2007).
- It is likely that past climatic trends will continue, with semi-arid areas becoming more arid (Druyan 2008).
- The high variability in precipitation will continue, and it is possible that the mean level of rain will be a little higher, though it is still uncertain. Even if successful predictions about the mean rainfall of a given season can be made, the distribution of precipitation throughout the season still cannot be predicted reliably (Druyan 2008).

Long-term Predictions

- Warming in Africa may be higher than the global average and persist throughout all seasons (IPCC 2007).
- The moister tropics may experience less warming than drier subtropical areas (IPCC 2007).
- There are discrepancies between models regarding expansion or contraction of vegetation: some models project significant drying of land, while others project a general wetting and expansion of vegetation into the Sahara (IPCC 2007; Hansen 2008).
- Drier conditions may result from land use changes and degradation – two factors that are not simulated by some models (IPCC 2007).

Impacts of Climate Change on Vulnerabilities



This section describes how global climate change is related to the major vulnerabilities of flooding, drought and desertification, and deforestation. It also describes some of the direct impacts of climate change on food security. This information is meant to explain the influence of a changing climate on landscapes, people, and livelihoods in West Africa.

Flooding

In West Africa, land beside rivers, deltas, estuaries and along the coast will become more vulnerable as climate change will likely increase the severity and frequency of flooding events in some regions (IPCC 2007). Many communities have adapted to living and farming in floodplains, and have altered their activities in relation to increased water levels. Severe flooding events may cause severe damage to these communities.

Precipitation

Annual rainy seasons and heavy storms are normal occurrences in parts of West Africa. The enhanced fluctuations in African climate have increased the spatial and temporal variability of rainfall in West Africa (IPCC 2007). Although a decline in annual rainfall has been observed since the early 1970s, the change was not equally distributed. In the tropical rain-forest zone, declines in mean annual precipitation have been around 4%, while along the Guinean coast there has been about a 10% increase in annual rainfall during the last 30 years (Nicholson et al. 2000). The unstable climate status is partially related to the occurrence of El Niño Southern Oscillation (ENSO) events. This status has caused unexpected flood events in arid countries (for example, Niger in 2005).

Rising global temperatures cause an intensification of the hydrologic cycle, as evaporation and levels of water vapor in the atmosphere are increased. More water vapor leads to more frequent and heavy precipitation events. The rainfall patterns in West Africa are controlled by complex interactions, which are difficult to predict. However, it has been predicted that the number of extremely wet years will increase in the 21st century (IPCC 2007). Shifts in seasonal runoff may contribute to flood risk for populations located in flood plains, causing damage to crops and structures, soil erosion, and landslides. Floods can also trigger malaria epidemics in arid and semi-arid locales (IPCC 2007).

Sea Level Rise

Although sea level rise is a gradual process, the impacts on local residents could be substantial and irreversible. Global climate change leads to a significant increase in the mean global sea level, amplifying the risk of flooding in costal areas (Nicholls and Lowe 2004). Already, many island nations have felt the impacts of this change. The intensified rate of ice melt at the poles will cause sea levels to rise. However, thermal expansion of ocean water is the major driver of sea level rise. As the temperature of the oceans increases, the same mass of water expands in volume. If climate change continues beyond the 21st century, substantial additional rises of sea level are likely, as both Greenland and Antarctica glaciers could become significant sources of water.

Coastal cities are home to 40% of the population in West Africa and this number is expected to rise. As many urban residents depend on regional production for food supplies, the impacts of climate change on agriculture will not only be felt in rural areas. Projected sea level rise will have significant impacts on large coastal cities due to the high concentrations of poor populations living in hazardous locations (IPCC 2007).

The Third Assessment Report of IPCC pointed out that the projected rise in sealevel from 1900 to 2100 was 9 – 88 cm, with a mid-range estimate of 48 cm (IPCC 2001). At the local scale, the change in sea level depends on the global mean sea level rise and regional deviations from the mean (Nicholls and Lowe 2004). Additional short-term variations on local scales are associated with extreme weather events such as storm surges. The results can also be considered regionally (see Nicholls 2004), and West Africa, along with the southern Mediterranean, East Africa, South Asia and South-East Asia, will likely have the largest absolute sea level increases compared to other parts of the world. The impact of sea level rise on coastal areas will likely intensify the need for WFP aid, as a growing number of people are displaced inland.

Drought and Desertification

Drought and desertification have already demonstrated significant impacts in West Africa. Residents of the region have been living with drought and desertification for many years and have developed methods for surviving in arid regions. The Sahel is particularly susceptible to these impacts due to the generally low and variable rainfall.

Droughts result from extended periods of below-normal rainfall and are naturally common in arid and semi-arid locations. Higher temperatures and low precipitation levels increase soil evaporation. When rains return, lands can recover if they are well managed. However, continued pressure on land during a drought can lead to land degradation (USGS 1997). The Sahelian drought of the 1970s and early 1980s had devastating impacts on land and livelihoods.

Desertification as defined by Chapter 12 of "Agenda 21" and the International Conventions on Desertification is degradation of the land in arid, semi-arid and sub-humid dry areas caused by climatic changes and human activities (Koohafkan 1996). The processes that lead to desertification create greater aridity and loss of vegetation, which can have an impact on local climate by decreasing the amount of water that is available for the local hydrological cycle. Human activities, such as overgrazing can increase land degradation and deforestation. The process is somewhat self-reinforcing, as reduced vegetation limits the capacity of a locale to hold and cycle water, leading to even drier conditions.

Climate change is expected to exacerbate these vulnerabilities as temperatures increase. On average, a decline in annual rainfall has been observed in West Africa since the end of the 1960s with a decrease of 20 to 40% from 1969-1990 as compared to the period from 1931-1960 (IPCC 2007). Climate change may cause evapotranspiration (evaporation of water and transpiration from plants) to exceed precipitation, leading to more severe and sustained droughts along with a decrease in summer rainfall.

Rising temperatures intensify the impacts of desertification, reducing resources such as freshwater, fertile soil, forests and vegetation (Zukang 2008). The complex feedback mechanisms associated with deforestation, changes in land cover and altered levels of dust in the atmosphere are particularly important in the persistence of drought in the Sahel (IPCC 2007). Increasing frequency of drought can also affect the interactions between natural and managed lands.

One of West Africa's most notable characteristics is the high contrast between wet and arid regions (some areas flood while others suffer from drought), resulting in an uneven distribution of water resources (IUCN 2004). While the Sahelian countries have limited supplies of freshwater, most countries in the humid tropical zone have abundant water. Africa is actually not water scarce, as the rainfall in some areas is adequate enough to meet the needs of the current population up to 7 times over if the proper irrigation techniques, water management, and technical infrastructure were used (AWDR 2006; Black 2006). However, the demand for water is increasing rapidly in most countries due to population growth, and will be a greater challenge with intensified periods of drought (AWDR, 2006).

A recent study identified in the latest IPCC report predicted that the number of extremely dry and wet days will increase during the present century. This study was based on four Global Climate Models (GCMs) for the Sahel region (Huntingford et. al. 2003). Other scenarios and modeling of droughts appear to be consistent with these scenarios. By the second half of the

21st century, the frequency and duration of droughts are expected to increase (IPCC 2007).

Recurrent drought resulting from climate variability accelerates desertification, which in turn contributes to the persistence of drought (IUCN 2004). Extreme weather events, including drought and heavy rains, will have dramatic impacts on already degraded soils and erosion (UN Sec. Gen. 2007). The creation of the Permanent Interstate Committee for Drought Control in the Sahel (CILSS) and the United Nations Conventions to Combat Desertification (UNDCCD) has facilitated significant collaborations in the region to address these challenges.

Drought and desertification directly affect livelihoods in the region, as most agriculture is rain-fed and soil fertility is quite variable. Droughts have contributed to migration, cultural separation and population dislocation (IPCC 2007). The importance of planning for the impacts of climate change in order to respond to the needs environmental refugees cannot be understated.

Deforestation

Research has shown that forest biomass has decreased in the West African Sahel to a level that cannot support the fuelwood needs of current population densities (Gonzalez 2001). In addition to settled communities, the needs of refugees for fuelwood further limit the ability of the regional vegetation to sustain these populations. Loss of forests leads to soil erosion and decreased soil moisture, limiting the agricultural productivity of a deforested area.

Forests are considerably important both environmentally and economically as they provide raw materials and medicinal products, house two-thirds of the world's species, protect watersheds, and support many other ecosystem services. However, due to the conversion of forested land to non-forested land from climate change, agriculture, fuel collection, urban development, and other causes the amount of total global forestland continues to decrease (UNEP 2006).

The FAO estimates the global rate of deforestation to be about 13 million hectares per year. On a positive note, the net rate of deforestation, which accounts for both the loss and expansion of forestland, has recently decreased. The FAO reports the net loss in forested area between the years 2000 and 2005 to be -7.3 million hectares a year, which is down from the -8.9 hectares estimated per year from 1990 to 2000. This decrease in the net rate of deforestation can be attributed to afforestation and forest preservation efforts. Afforestation is the establishment of forests in areas that were not previously forested. Some regions that have experienced considerable losses of forestland include South America, Africa, and Asia. Between 2000 and 2005 South America experienced the largest loss of forestland, followed closely by Africa which lost 4 million hectares per year (FAO Forest 2006).

West Africa is one of the least forested regions of Africa, with only 12% of its land area covered by forests. Guinea-Bissau is the most forested country within West Africa with 60.5% of its land area in forest, and Mauritania the least with only 0.3% (FAO Forest 2003). In general, forested area within West Africa has become considerably vulnerable to deforestation since the 1970s due to the increased use of wood fuel, drought, overgrazing, urbanization, and conflict. It is estimated that from 1990 to 2000, over 12 million hectares of forest were lost in the West Africa region alone (Golubiewski 2007).

Particular areas of concern include the Guinea Forest, which spans six West African countries and has been noted as one of the world's important "hotspots" for biodiversity. Biodiversity supports the functioning of ecosystems and promotes the natural services which many in poverty depend upon, such as water filtration and pollination of crops. Due to logging and agricultural activities this forest has become fragmented and greatly reduced in size, with only 15% of the original forest remaining. Countries with the highest rates of deforestation include Nigeria and Cote d'Ivoire, which together have an estimated annual deforestation rate of 663,000 hectares (Golubiewski 2007).

While human activities are a major factor in deforestation, increasing global temperatures also reduce the ability of forests to survive. Higher temperatures raise the rate of evapotranspiration from trees, the daily water needs of forests increase. If the region is also subject to drought, it may be difficult for trees to survive or for seedlings to develop. Forests are a very important piece of local hydrological cycles, influencing local precipitation and soil moisture. Once an area becomes denuded, soil dries, groundwater infiltration may decline, and the amount of water in the local cycle decreases rapidly. This process often results in desertification, which leaves the land in a state that makes regeneration or restoration very difficult.

The long-term affects of climate change on forests in West Africa are difficult to predict, as many variables must be considered. For instance, the way that humans use land can influence climatic patterns. Drier conditions may result from land use changes and degradation which are not simulated by some of the climate models (IPCC 2007). There is currently no consensus on whether changes in land cover on a small scale are highly influential in the wider regional climate. However, patches of overgrazing and deforestation in certain local areas are influencing climate at the local scale (Taylor et al. 2002; Ward 2008). This is a factor that can be addressed through improved land management. While changes in land use may have played a role in the Sahelian drought by causing a later onset of July rains, it is probably not the main cause of the drought (Taylor et al. 2002). It is expected that the impacts of reduced forest and vegetation cover will have a stronger impact on regional climate in coming years (Taylor et al. 2002).

Food Security

Climate change directly impacts food security in West Africa, largely because most West Africans rely on agriculture for their livelihood and sustenance. This region has coped with extreme conditions for many years, but climate change is expected to exacerbate already existing agricultural challenges. Variations in temperature, precipitation, and the length of the growing season directly effect crop yields. Repetitive cultivation of marginal lands has increased land degradation, altering soil fertility and depleting essential nutrients. As temperatures increase, the influences of climate variability on periods of drought and flood, as well as long term changes in temperature may impact food availability, access, and acquisition of nutrients directly and indirectly (IPCC 2007).

Rain-fed agriculture dominates the region, with a high dependency on an increasingly unreliable source of water. Crops grown in drought-prone areas are especially vulnerable. Although individual crops are affected by climate variability in distinct ways, research shows that cowpea, maize, and millet are expected to be impacted most by climate change. This is due to the late-season planting of these particular crops, and their vulnerability to insufficient rain from June to September (Adejuwon 2006). The IPCC 2007 report estimated that parts of the Sahara will experience agricultural losses of 2-7% of their GDP by 2100 (IPCC 2007). Conversely, projections that cite increased rainfall combined with potentially heightened solar radiation as a result of reduced cloud cover estimate an increase in agricultural yields in the first half of this century. In the second half of the 21st century, these models predict a decrease in yields due to increased temperatures and atmospheric carbon dioxide (Adejuwon 2006).

Intra-annual temperature oscillations impact crops through the inability of particular varieties to cope with temperatures above or below a certain threshold (Adejuwon 2006). The impact of interannual temperature variations on crops is difficult to predict for the West African region. For example, projections cite an initial increase in maize yields with rising temperatures, followed by a net decrease in yields between the near-term and 2099 (Adejuwon 2006). For farmers, seasonal prediction is a powerful tool to manage the potential effects of temperature fluctuations on yields. Access to projections regarding rainfall would directly enable farmers to adjust their crops or cropping methods accordingly.

Though there is a lack of consensus regarding the long-term climate predictions for West Africa, it is certain that changes in rainfall and temperature are directly linked to food security. Integrating ecologically sustainable agricultural practices will be central to maintaining and improving food security in West Africa. Strategies that focus on locally maximizing yields are favorable and practical in the short-term. Maintaining a focus on the long-term adaptability of crops and cropping choices is also central to food security. Proactive, sustainable agricultural techniques can improve resilience and temper the impacts of climate change on food security. Choices made in West Africa should consider factors beyond resistance to drought or disease, and should include cultural preferences, palatability and seed storage capacity (IPCC 2007).

In this report we address four issue areas that, as a result of global climate change, will affect the WFP's mission and work in West Africa. Though all the effects of climate change are interlinked, program recommendations have been divided into four chapters according to the vulnerability categories of: flooding, drought and desertification, deforestation, and direct impacts on food security. Though these programs have been chosen with the West Africa region in mind, there is a high degree of transferability to other regions where the WFP operates.

Introduction to Recommendation Chapters

Each issue chapter begins with an introduction that includes climate change information specifically relevant to the vulnerability addressed in the chapter and the ways in which it will impact the WFP's programs in West Africa. Each chapter contains three to six program recommendations, which include a descriptive overview of the recommendation, implementation considerations, relevancy for the WFP, possible challenges, and examples of successful application. In deciding which programs to recommend to the WFP, elements such as cultural appropriateness, financial and time constraints, regional environmental characteristics and the potential links with other WFP programs were considered.

The program recommendations in each chapter are designed to address particular vulnerabilities brought about by climate change. However, it should be noted that some programs will be beneficial in more than one issue area. In many cases it is likely that using a combination of programs and approaches will be the best solution, addressing concurrent problems simultaneously.

When the WFP undertakes evaluation of these and other program recommendations, we recommend that environmental indicators be incorporated into the process. This more comprehensive evaluation strategy can help reduce the potential for unintentionally inflicting environmental damage, which may actually reduce long-term food security. In addition, these types of indicators can help determine if programs that were designed with environmental intentions are accomplishing their goals. The WFP's Environmental Review Guidelines (WFP 1999) provide valuable tools for developing environmental indicators for program assessment. Indicators will likely vary by project, but may include items such as estimated amount of carbon sequestered, flood damage avoided, or number of trees planted which are still living after a period of time.

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Recommendation Chapter 1: Flooding

Floods can lead to losses of human and animal lives, agricultural soil, crops, and infrastructure such as roads, housing, and farm structures. The extent to which global climate change is altering rainfall patterns is difficult to determine because of the complexity of the mechanisms that affect rainfall, but it has been predicted that the number of extremely wet years will increase in the 21st century (IPCC 2007). In addition to rainfall, sea level rise is expected to increase the occurrence of flooding in West Africa in coastal and deltaic areas (IPCC 2007).

Although sea level rise is a slow and uncertain process, the impacts on local residents could be substantial and irreversible. As sea levels rise, WFP aid to these areas may intensify as a growing number of people have to move inland and to higher ground. In addition, saltwater intrusion in these coastal areas may damage crops in the region, leading to a higher reliance on food aid. West Africa's currently low adaptive capacity may aggravate the losses caused by floods (IPCC 2007).

This chapter contains three recommendations that the WFP can use to assist vulnerable populations in adapting to flood situations influenced by climate change.

These programs include:
• use of flood mitigation structures
• strategies for sea level rise
• aquaculture

Recommendation 1.1: Mitigation Structures

Overview

There are a variety of physical structures that may be used to adapt to the increased flooding events that will occur with climate change. These structures can be used to reduce damage caused to crops, property, and livelihoods and to decrease soil erosion. Some structures have the added benefit of taking advantage of floodwaters for agricultural use. These structures can also be used to secure transportation routes that food aid is heavily reliant upon. Building these types of structures will prepare communities for future floods and will also make them better off in the long run because they will not have to use so much of their limited resources to recover from flood damage. The construction and maintenance of many structures could be done in partnership with the community.

Implementation Considerations

Determining the particular structure or combination of structures to use in a given area is a technical process and should be determined by engineering professionals. Decisions may be based on location,

Figure 1: Examples of Flood Management Structures

Structure	Materials	Benefits
Dam-fields: "Dam-fields are constructed between the mouth of a gully and its upper end, using the topsoil which has been carried down the slopes and hills by flood waters. The topsoil is deposited in the dammed areas. In this way, flood water is retained in the upper dams and then used to irrigate the crops cultivated in the dammed fields at the lower level. When the dammed area is full of soil, new dams are constructed on the accumulated soil, and the newly formed lands are available for tilling" (UNFCCCa 2008)	Locally available materials, such as soil and rocks; tools	Controls soil erosion; Takes advantage of runoff; Higher crop yields
Diversion Walls: Walls that are built in the bends of a river "to divert some of the soil and water." "Heavy flat stones are placed upright in a line one right next to the other, alternating larger and smaller stones. A second layer of vertical stones is wedged into the gaps between the first line of stones, until a small wall is erected. The force of the river presses one stone against the other and, in effect, to "tie them together" (UNFCCCb 2008).	Stone, tools	Diverts water for irrigation; Higher crop yields
Vegetative Barriers: "Vegetative barriers are narrow, permanent strips of vegetation established in parallel rows and perpendicular to the dominant slope of the field. They may be grown on cropland fields, on slopes less than or greater than 10%, where water and wind erosion is a problem, or where water needs to be conserved" (UNFCCCc 2008).	Stiff stemmed, erect, tall, dense perennial vegetation	Controls soil erosion; Possible use as fodder; Possible income source

topography, soil type, frequency and source of floods, cultural appropriateness, and availability of materials. Detailing which structures are appropriate in specific contexts is beyond the scope of this report. However, there are several recommendations for considerations that should be part of the planning and construction of flood-related structures.

Whenever possible, structures should be "built back better," both in terms of materials used, planning, and good workmanship, to ensure that they are able to withstand repeated flooding episodes (Sheeran 2008). In this same vein, materials used should be environmentally friendly and flood-resistant. It would be particularly efficient and beneficial if structures are designed for more than one purpose or use. For instance, some vegetative barriers help to control soil erosion, can be harvested for supplementary income, and act as a carbon sink. Likewise, walls can be built that divert floodwaters for both protecting and irrigating crops.

Relevancy for the WFP

The construction of these structures may be built in partnership with the community. In addition, it may be helpful to teach community members how to maintain structures, so the WFP is not required to maintain or rebuild them as often. Training people to build and maintain these structures can encourage development, self-sufficiency, and food security.

Challenges

According to the WFP's Environmental Review Guidelines, "certain infrastructure and natural resource management activities can pose moderate to high risk of adverse environmental effects if they are not properly designed and implemented" (WFP 1999). This means that proper site and structure assessment, planning, and construction must be done to ensure that mitigation structures do not cause more problems than they solve.

The construction of some of these structures requires engineering expertise and heavy machinery. This may pose a financial challenge for implementation in some instances. Partnering with other organizations which specialize in these activities could be useful (see Winrock International, under Supplemental Resources).

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Example of Success

Flood Management Structures in Kenya

The Kenyan Red Cross Society has been successful in implementing a program that incorporates community participation into the construction and maintenance of flood mitigation structures through a flood preparedness initiative in Nyanza, Kenya (UNFCCCd 2008). Flooding occurs in this area when Lake Victoria expands due to heavy rain, destroying crops, property, and livelihoods. In addition, soil erosion takes place because of the level of deforestation that has occurred. The Kenyan Red Cross Society (KRC) has been training communities "to prevent and respond to floods.'

The KRC has provided training in waterway drainage and desilting which helps to keep villages from being flooded. Proper drainage of the excess water is ensured through the enlarging of riverbeds, draining of existing waterways, and desilting after each flood. The KRC has also taught community members how to build trenches and dams around their plots of land. Villagers are trained in dyke maintenance, and also plant trees, often eucalyptus, along the edges to hold the soil in place (UNFCCCd 2008).

Recommendation 1.2: Sea Level Rise Strategies

Overview

A significant global mean sea level rise (SLR) is expected due to human-induced warming during the 21st century (IPCC 2007; Nicholls and Lowe 2004). The risk of SLR and recent coastal erosion are among the most serious issues facing West Africa, especially considering that 40% of the population lives in coastal cities (IPCC 2007). Projections have estimated that the 500 km of coastline between Accra and the Niger Delta will become a continuous urban megalopolis with more than 50 million inhabitants by 2020, and will be particularly vulnerable due to the poverty of the population (IPCC 2007). As a result of increased flooding risk and storm intensity, SLR will affect food security in West Africa.

A recent study has projected which areas in Africa would be affected if the sea level rises between one and six meters (U. Arizona 2008). With a one-meter rise, the southeast of Cameroon (Figure 2), several spots along the west coast of Mauritania, Senegal, the Gambia, Guinea-Bissau, Guinea, Sierra Leone, and islands in Cape Verde will be affected (Figure 3). If there is a six-meter rise in sea level, the affected areas will be extended greatly (Figures 4, 5). The impact of SLR on people is amplified because a large portion of the affected areas is densely populated.

Implementation Considerations

Different from other natural disasters, SLR is a slow process with many uncertainties. Therefore, strategies against loss are normally preventative measures to adapt to the gradual change, and can be grouped into three categories: protection methods, accommodation methods, and retreat measures (IPCC 1990; Nicholls 2003).

Protection: Protection against SLR involves construction of solid structures (such as sea walls and dikes) as defensive measures. There are also "soft" approaches (such as dunes and vegetation) that can be used to protect areas and to allow existing land uses to continue. This strategy is especially important for countries facing emergent threats from SLR, such as Cameroon.

Human activities such as filling wetlands and damming rivers can destroy the natural protection provided by these features, and should be limited. The protection of natural buffers, such as wetlands and mangroves should be prioritized, especially for countries where coastal erosion and loss of wetlands are severe (as in Cote d'Ivoire).

Accommodation: This strategy allows people to continue to use the land at risk without attempting to prevent the land from being flooded. This option includes erecting emergency flood shelters, elevating buildings on piles, converting agriculture to fish farming (for more information refer to recommendation 1.3), or growing flood or salt tolerant crops.

Retreat: Under this approach, no effort is made to protect the land from rising water. The coastal zone is abandoned and ecosystems are allowed to shift inland. In West Africa, a policy of retreat may be considered under the precautionary principle, and the potential loss of coastal land and movement of populations should be kept in mind when planning development programs. It is advised that WFP does not locate important regional centers or long-term projects along vulnerable coastlines.

Of the above strategies, it is recommended that the WFP concentrate its efforts on the protection of wetlands because they are important contributors of food sources and water filtration, and act as buffers to SLR by protecting fertile land near river deltas.

Relevancy for the WFP

In order to protect wetlands and mangroves, understanding and appreciation by local residents of their ecological significance is crucial. Due to the gradual and slow process of SLR, it is hard for local people to recognize the emergence and severity of negative impacts. The WFP could organize informative workshops to educate government or community leaders regarding the importance of protecting wetlands.

The movement of populations in Africa, often in search of cultivatable land, has been a factor in some cases of local ecosystem degradation, including that of wetlands and mangroves. Projects that promote sustainable agriculture techniques, protection of wetlands and mangroves, and use of flooded coastal areas for aquaculture (please see recommendation 1.3) may help to reduce the need for farmers to move and over-cultivate land.

Challenges

The reluctance of coastal residents to move to inland areas is a challenge that the WFP would face if a strategy of retreat is encouraged. The pattern and rate of SLR is still unclear and uncertain. Improving scientific and public understanding of the problem would be a critical component for the WFP to develop a response strategy (IPCC 1990). To increase public understanding, the WFP could incorporate SLR information into other programs, such as food-for-education.

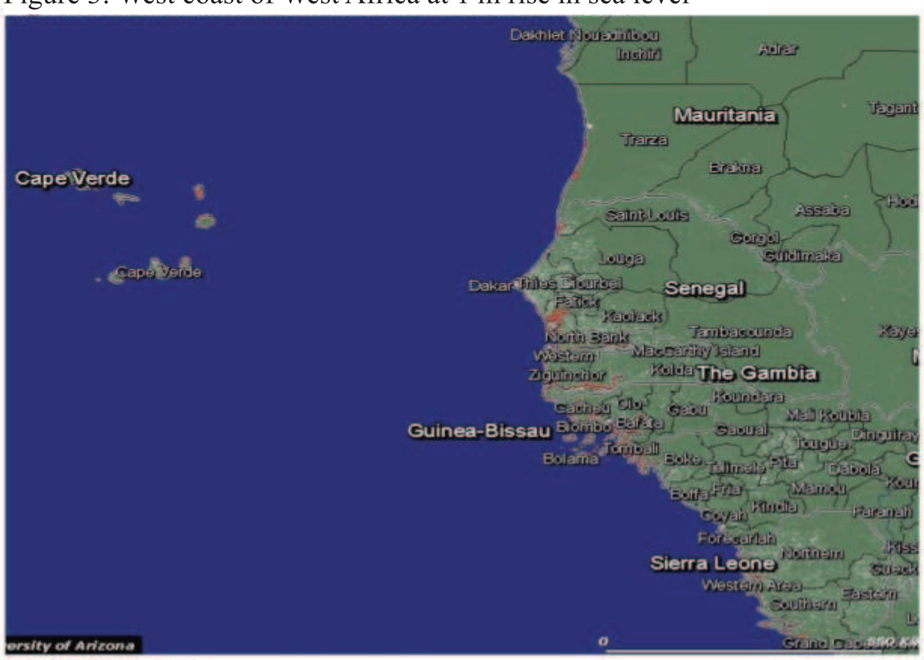
The complexity of the SLR issue makes the scientific understanding of it another challenge. Because SLR is a global issue and there are many other organizations and institutions researching it, the WFP may benefit from setting up partnerships with them by sharing information: the WFP could provide the frontline data while the other organizations could provide warning information. For example, it is reported that the available information on coastal land elevation is poor, and there are relatively few countries with reliable data to determine how many people and how much development is at risk (IPCC 1990). The WFP could set up "Food-for-Information" programs to invite local people, who are more familiar with the local environment, to observe and report any changes in coastal regions. This information would also be very useful to other research institutions.

The third challenge would be the potential impacts on ecosystems of these response strategies. Under the retreat option, wetlands could remain largely intact, as they would be able to migrate landward as the sea level rises, though the total area of wetlands would still decline. Under the protection option, if structures were built to protect against salt water incursion, for example, the structures would block wetlands' landward migration, and a much larger proportion of these ecosystems would be lost.

Figure 2: Cameroon at 1 m rise in sea level

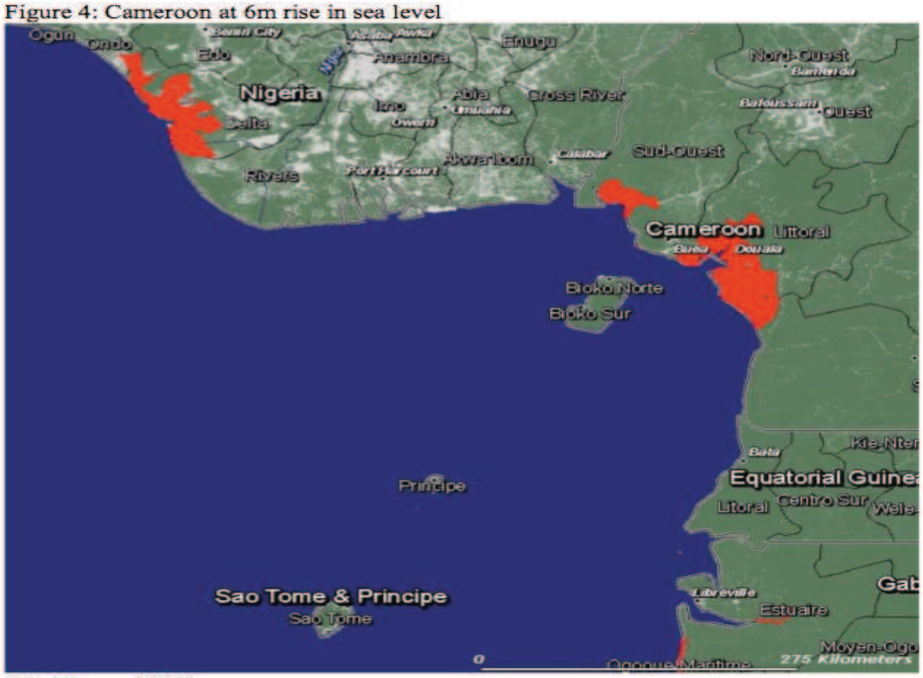
(U. Arizona 2008)

Figure 3: West coast of West Africa at 1 m rise in sea level



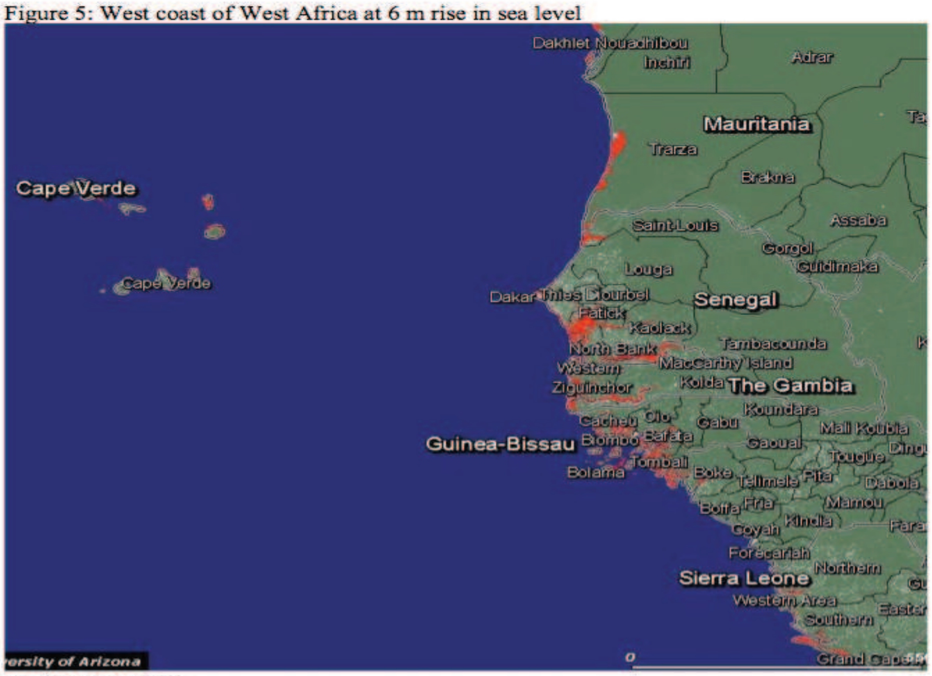
(U. Arizona 2008)

Figure 4: Cameroon at 6m rise in sea level



(U. Arizona 2008)

Figure 5: West coast of West Africa at 6 m rise in sea level



(U. Arizona 2008)

Recommendation 1.3: Aquaculture in Floodplains

Overview

Aquaculture, or fish farming, is used to augment wild fish catches, or to cultivate fish where wild fish are not available. It is the fastest growing food industry worldwide (Peterson and Kalende 2006). Global fisheries are increasingly threatened, which is particularly evident off the West African coast. A further decline is fish stocks likely due to a growing European demand for fish (Lafraniere 2008), and alternative fishing methods can present promising strategies for feeding local populations. Aquaculture can be used to supplement ocean catches and improve farmer livelihoods in poor, rural areas. It may also be used in floodplains. This method of cultivation employs marginal areas that may not be useable for growing crops during certain periods of the year, particularly in areas prone to flooding. As climate change increases storm severity, leading to higher flood risks, agriculturally productive land may become more vulnerable to mounting water levels. This may occur inland as a result of greater precipitation, as well as in coastal areas susceptible to rising sea levels.

Land that is otherwise unsuitable for use can become productive by cultivating fish in floodplains during the rainy season, through a system of enclosing an area with netting in order to maintain fish stocks. Aquaculture can promote high-quality, nutrient-dense food production and enhance farmer income in areas with regular rainy seasons. Cropping methods for this type of system include alternating rice with fish, or concurrent rice and fish cultivation. A common fish used in indoor aquaculture facilities in the United States is tilapia, a native African variety. Local, culturally appropriate fish adapted to flood-prone areas should be first considered in West African aquaculture operations. By promoting localized aquaculture, areas will become less dependent on food aid. These systems can also be community-managed for greater access, control and success.

Implementation Considerations

Floodplains are generally flat, dry areas of alluvial deposits near a stream or other water body that are susceptible to periodic inundation of water (Peterson and Kalende 2006). Aquaculture in these areas is susceptible to storm surges and/or drying, and operations located near coastal areas are particularly susceptible to saltwater incursion as sea levels rise. They may also be affected by upstream dams and irrigation. Use of man-made wetlands, could be considered for these operations. The ability of wetlands to purify water may help to maintain healthy fish stocks, serving as a sanctuary and nursery for fish and other animals (Peterson and Kalende 2006).

The start-up costs associated with aquaculture are minimal. These include the fingerlings (juvenile fish) and the netting/fencing to maintain the fish stock. Typical netting in floodplain aquaculture uses a material such as bamboo, but materials vary for each location. The expense of netting is incurred when setting up an aquaculture system, but the nets typically last for more than one rainy season. Natural vegetative fencing can also be used to lower net costs, though the labor of planting should be included in cost considerations (DMI 2008).

If rice is being grown, there are labor costs to plant and harvest, in addition to harvesting the fish at the end of the flood period. Consider both family and hired labor to guard, harvest and perform post-harvest operations as variable costs. Also, some farmers may consider adding nutritional inputs to quickly add body mass to fish populations; this may be preferable in places with shorter rainy seasons. These feed materials may include agricultural by-products, such as rice bran, cotton waste and fishmeal. Profits from aquaculture and rice production, if cultivated together, are likely to offset start-up costs and have been shown to bolster net income to farmers (Dey and Prein 2004).

If the alternating fish and rice method is used, there may be reduced need for dry season fertilizer input as a result of nutrient residues left in the floodplain sediment from fish excrement. During the rainy season, this contribution to soil fertility, paired with evidence that there is reduced need for pesticides in these systems, has been found to raise rice productivity and profits. If pesticide application on rice is considered, it should be part of an Integrated Pest Management system, so as to not negatively impact fish populations (Graham et al. 2007).

Using floodplains for aquaculture is appropriate on a local level, and can be administered through community management practices. There are three typical operation forms: Small-scale homestead pens; trap pond management; and enhancement of wild catch through improved traditional gear (DMI 2008). The latter operation is applicable to both aquaculture and open water bodies and will not be the focus of this recommendation. In general, production level is limited to the frequency of flood, length of water capture period and size of floodplain.

Climate Impacts on Implementation

With rising global temperatures and greater storm severity, West African fisheries will likely be impacted, wherever these operations are located. Simulations based on the National Center for Atmospheric Research's Global Climate Model (NCAR GCM) reported in the Fourth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC) found that when carbon dioxide was doubled in their model, the resulting rise in extreme wind turbulence was found to reduce fishery productivity by 50-60%; with a 10% decline in spawning ground productivity and an increase of 3% in the main feeding grounds (IPCC 2007). In relation to the environmental impact of aquaculture, biodiversity and wild fish population abundance were not found to be impacted by aquaculture operations in case studies in Bangladesh and Vietnam (Dey and Prein 2004).

West Africa is a vast region with differing rainy seasons. In areas with a bimodal rainy season (e.g. along the Guinea coast), two short periods of rain will allow for two aquaculture cycles, rather than one cycle in other areas of West Africa. These operations will depend on precipitation levels and localized flood patterns. Ideally, floodplains would maintain minimal water levels for at least 4-5 months for maximizing fish production (DMI 2008). Unpredictable, sporadic flooding is less desirable for raising fish, unless there is means to capture enough of the incoming water for use.

Relevancy for the WFP

To implement a successful aquaculture operation, education may be needed on local fish varieties and fingerling identification, as well as rice varieties, with consideration of submergence tolerance of deepwater rice and elongation ability. The latter depends on water depth of the usable floodplain. Additionally, business education may also be needed in some areas to adapt this farming technique to the local market.

The role of community support and involvement reinforces social acceptability of these localized operations and can be used to strengthen economic development and encourage better local nutrition. Aquaculture is self-sustaining once a community establishes a method of entrapment (e.g. nets made from bamboo, native vegetation growing in the floodplain acting as a natural habitat for species or a flood embankment of some form) and management mechanism.

Aquaculture may be classified as a development project, supporting livelihoods and food security with patterned fishing cycles. The rice-fish technique is easily reproducible and appropriate to West Africa. From case studies in Bangladesh and Vietnam, areas of social accord were a prerequisite for success (Dey and Prein 2004).

Challenges

Property rights may be a consideration in some areas when developing aquaculture schemes, though case studies have shown success with both landowners and landless laborers. During the dry season cultivation is secured by land tenure, but during the flood season land is not visible and water areas often become community property. This allows for community-based management as appropriate and effective (Dey and Prein 2004).

During the rainy season, maintaining community management is a key to high aquaculture yields. To overcome start-up costs that may limit participation in an aquaculture operation, subsidies or loans for netting could be administered to farmers. Communities could reinvest in future net maintenance, and repay these loans with the surplus from selling fish.

The challenge of keeping fish alive during the dry season is a major concern in some areas; in parts of the Sahel, deep wells or holes are dug to support fish until the next rainy season (Peterson and Kalende 2006). In other areas, smaller supplemental ponds may be needed as a fish refuge during periods of drought. In addition, outside source pollution may contaminate floodplains in some areas, reducing fish stocks and making them less suitable for human consumption.

Another major concern in West Africa is food spoilage. In some areas, spoilage by as much as 50% of fish catches has been reported (Peterson and Kalende 2006). To address this issue, many communities smoke fish as a means of preservation. As aquaculture operations extend to areas not accustomed to fish preparation, education may be needed on smoking techniques and other means of storage.

Example of Success

Aquaculture in Floodplains in Bangladesh and Vietnam

A study conducted by the Worldfish Center tested two types of rice-fish production between 1998-2000: 1) Alternating rice-fish culture (during the fallow period) in deep floodplains through community-based management, and 2) Concurrent rice-fish in shallow floodplains.

In Bangladesh, there were three types of trial sites: 1) Small area (<5 ha) with 30-60% perimeter fencing and minimal feeding, 2) Small area (<5 ha) with less than 30% perimeter fencing and minimal feeding, and 3) Large area (10-20 ha) with less than 30% perimeter fencing and moderate feeding. Participating group (i.e. farmers) size averaged 38 in Bangladesh, including both landowners and landless laborers.

This study found an improvement in fish production in Vietnam and Bangladesh in shallow (<50-150 cm) flooded areas by around 600 kg/ha/year and in deep (150-250 cm) flooded areas by up to 1,500 kg/ha/year. Production resulted in 20-85% additional profitability over wild fishing methods.

In Vietnam, the alternating method produced an additional income of US $135/ha and the concurrent method, US $346/ha; in Bangladesh, the alternating method produced an increase of US $437/ha and the concurrent method, US $138/ha. Both alternate rice-fish and concurrent rice-fish were found to be profitable, though the alternating system proved to have a higher net increase in profit (as fish yields were higher) in Bangladesh, but a lower net increase in Vietnam. In Bangladesh, culture periods ranged from 150-210 days, whereas in Vietnam, the average was 210 days.

Though most operations were profitable, some farmers in Bangladesh incurred net losses from natural events (e.g. floods and storms), and/or poor water quality. Per hectare cost of community-based aquaculture in floodplains was found to vary from USD $168 to USD $811. Fingerlings (juvenile fish) represented 49-75% of total costs, whereas fencing was only 4-33% of the total costs (with less than 30% perimeter fencing). Costs varied due to site specifications, management and type of enclosure. There were no reported reductions in rice yields nor wild fish catch.

In conclusion, the study reported that floodplain aquaculture was technically feasible, economically viable, socially acceptable and ecologically non-destructive in Bangladesh and Vietnam. These methods should be transferable to West Africa, particularly in locations prone to flooding where rice production is common (Dey and Prein 2004).

Recommendation Chapter 2:
Drought & Desertification

Drought and desertification directly affect the livelihoods of people in the West Africa region, as most agriculture is rain-fed and soil fertility is quite variable. According to the Fourth Assessment Report of the IPCC, stresses resulting from droughts and floods in Africa are increasing, and the low adaptive capacity has aggravated the losses caused by these disasters (IPCC 2007). In addition, West Africa has a much shorter weather prediction lead time compared to other areas of Africa. Higher temperatures and lower precipitation lead to an increase in the frequency and the intensity of droughts. If lands do not recover from periods of drought, it is predicted that desertification or land degradation will intensify, reducing water availability, soil fertility, forests and vegetation cover.

Water availability is already a problem in parts of Africa, and the situation is further complicated by frequent droughts and increasing desertification brought about by climate change in combination with ineffective water management programs. Because of unique physical, geological and socio-economic characteristics, the availability of water varies considerably, even within countries. Currently, the hydro-agricultural potential of West Africa has not been reached and the level of water control in West Africa has much room for improvement (IUCN 2004).

The following section will outline important climate change adaptation and mitigation strategies that the WFP might consider to address drought and desertification in West Africa. The five recommendations include:

- weather index insurance
- rain gauges and sowing charts for crop planning
- strategies to reduce desertification
- rainwater storage
- micro-irrigation

Recommendation 2.1: Weather Index Insurance to Reduce Risk for Farmers

Overview

Weather index insurance (index insurance) for agriculture is a valuable drought-related adaptation program option for the World Food Programme in West Africa as it works to maintain food security and protect the livelihoods of populations. Index insurance contracts insure a weather index (e.g. seasonal rainfall needed to grow a crop) rather than a crop like traditional crop insurance contracts (Osgood). Traditional crop insurance can be exploited by farmers who allow crops to fail to collect insurance payments (Hellmuth 2007). Index insurance programs are being developed to support rain-fed agriculture in several countries, including Malawi, Ethiopia, and India. Index insurance is beneficial to farmers in times of drought-related crop failure because insurers pay farmers immediately (Hellmuth 2007). With these payouts farmers do not suffer financially or sell assets to survive, and can continue to farm when rains returns (Hellmuth 2007). Index insurance protects farmers and allows them to take risks to increase yields, such as investment in fertilizer or advanced seeds, which can increase overall yields (Hellmuth 2007). Since West Africa has several different land types and climate zones, index insurance for flood, drought, and other weather variations should be considered. The International Research Institute for Climate and Society (IRI) is researching index insurance for the climate-related hazards of locust, fire, malaria, and livestock disease (Osgood).

The index is an established relationship between historical rainfall records and crop yields. The index is the set amount of rainfall needed by a crop in each stage of growth in order not to fail (Osgood). The Food and Agricultural Organization (FAO) of the United Nations has established a crop-specific indicator for rainfall amounts and yields known as the Water Requirement Satisfaction Index (WRSI). For this reason, index insurance programs utilize precipitation data provided by meteorological collection stations (Osgood). If precipitation levels fall out of a range established by the index—and is low or high enough to cause crop failure—the insurer will pay farmers the amount of the loan, so the farmer can survive without market income from the crop (Osgood). If precipitation levels are within index range the farmer uses proceeds from yields and insurance investment to pay off the loan (Osgood). The additional profit, beyond the amount owed on the loan, is retained by the farmer. Overall, the farmer pays the full financial cost of program (Osgood). For this reason banks also benefit from index insurance by expanding their lending portfolios in a managed manner (Syroka 2007).

Several other international organizations partner to recommend and/or financially support index insurance. For example, The World Bank recommended index insurance in its 2008 World Development Report, stating that "index insurance can reduce risks and cover loans to finance new technologies" (World Bank 2007).

Implementation of index insurance requires several inputs. Inputs include privately-owned lands with potential for rain-fed agriculture, an index, climate information from meteorological entities, banks to provide loans, insurance companies to provide policies, subsidies for farmer start-up costs, and continued subsidies for meteorological data collection and contract design assistance (World Bank 2007, Osgood).

Implementation Considerations

Time Considerations

Once the meteorological data system, crop, index, bank, and insurance provider are selected, implementation is dependent on the scale of the index insurance program. Small-scale index insurance programs, such as the Malawi pilot program (see "Example of Success" below) can be operational in six months to a year, while national programs could take one to several years to fully implement (Hellmuth 2007).

Financial Considerations

Some index insurance contracts offer bundled loans that pair bank loans with insurance policies and allow farmers to purchase agricultural inputs (e.g. seeds and fertilizer) with credit from the loan. Farmers can expect a net gain in farming production profits and can then repay the loan themselves (Hellmuth 2007). Index insurance programs may need financial support initially, but will become more self-sustaining in the long-run, as farmers pay for the full financial cost of program (Osgood). Elements of index insurance that often need subsidies are meteorological data collection, assistance for contract design (Osgood), and start-up costs for farmers (World Bank 2007).

Scale Considerations

Index Insurance has the potential to be implemented on a local, regional, or national level. Two local-level, pilot index insurance programs were implemented successfully in Malawi between 2005 and 2007 (Syroka 2007). The majority of West Africa's population work in rain fed agriculture and a large portion of land in this region is subject to periods of drought (Hellmuth 2007). This combination of a rain fed majority and prevalent drought make index insurance a viable policy for this area. One benefit of national index insurance is the fact that weather risk is spread across a larger farmland area and higher number of insurance holders. Smaller, local programs are higher risk because if all local crops fail at the same time, insurance companies may be strained by larger simultaneous payouts.

Infrastructure Considerations

Meteorological data centers must be operational to collect measurements, and banks must be able to provide affordable loans. Insurance companies must exist and be willing to provide contracts with insurance premiums that are affordable for the farmer, while supportive of their business requirements (Syroka 2007). It is important that insurance contracts are understandable for stakeholders, with minimal training.

Relevancy for the WFP

The development of contracts, collection of meteorological data, educational needs, and communication requirements of index insurance are all potential options for WFP involvement. The farmers are not expected to need a high level of education to take out insurance policies and loans, but rather an awareness of how to use the seeds and fertilizers that come with the loans, and how to properly communicate with these financial institutions should a conflict arise.

One option is the creation of a cash or food-for-training development program, in which farmers, insurance companies, and workers of meteorological stations undergo training for their respective specialties of work, and are provided with food during the training period. Food allocations could be phased out as crop productivity increases.

Since index insurance provides financial support for farmers in periods of drought and can increase local production of food, it has the potential of decreasing food insecurity. Therefore, WFP's could view current support for index insurance as an investment that could lower future food aid needs.

Challenges

One limitation of index-insurance is the amount of experience that poor rural populations may have with insurance contracts and loans. A second limitation is high transaction costs for micro-insurance policies. A third limitation is the impact of weather shock on an entire region. Weather shocks may exceed local coping mechanisms, such as local credit and labor supply. Therefore, large financial institutions may be better for supporting this type of program.

Public outreach campaigns could help to mitigate the distrust that community members may hold toward these unfamiliar financial institutions. If mistrust is severe, insurance from local banking institutions may be more appropriate than a national bank. However, as small local institutions may lack the necessary coping mechanisms for this type of insurance, larger institutions may be better suited to handle these demands. The choice of scale should be appropriate for local conditions. Overall, it is recommended that the WFP consider national or multinational index insurance plans that are able to respond to different climate outcomes and shocks across a variety of land types.

Public-private partnerships, where insurers and governments spread risk between themselves to fund disaster preparedness, will increase the effectiveness of these programs. The establishment of additional weather monitoring centers in some areas may be needed to ensure accurate measurement collection.

Example of Success

Index Insurance in Malawi

Malawi was an ideal country for an index insurance program because over 80% of its citizens work in farming and 90% of its agriculture is rain-fed (Hellmuth 2007). In July of 2005, the World Bank initiated the Malawi index insurance pilot program with a stakeholders meeting (Hellmuth 2007). The key organizations of this program included: National Smallholder Farmers Association of Malawi (NASFAM), the Malawi Rural Finance Company (MRFC), Opportunity International Banking Malawi (OIBM), Malawi Met Office (meteorological office), and others organizations. The Malawi Met Office is ideal for the program, with over 30 years of operation, 21 main synoptic stations, and over 200 rain gauges (Syroka 2007).

In Malawi bundle loans cover the costs of insurance premium, seed, interest, and tax and were provided by OIBM and MRFC (Syroka 2007). The risk of insurance policy was spread across seven insurance providers that have unified as the Insurance Association of Malawi (Syroka 2007). NASFAM sold groundnut seed in 2005 pilot and groundnut and hybrid maize in the 2006 pilot (Syroka 2007). In 2005, approximately nine hundred farmers participated and the sum insured a total of USD $35,000 (Syroka 2007). In 2006, approximately two thousand and five hundred farmers participated and the sum insured total USD $110,000 (Syroka 2007).

An example of a bundle loan in Malawi:
A bundle loan total is USD $ 39-35 (4,500 Malawi Kwacha)/acre. Included in this bundle was ground nut seed for USD $25, interest of USD $ 7, insurance premium of USD $ 2, and tax of USD $ 0.50. The prices of each component in the bundle varied by site, and the insurance price was equal to Average (payout) + Loading (Value of Risk – Average) (Vicarelli). The sum of the loan and interest was equal to the maximum liability of the insurance (Vicarelli).

Success of Malawi Pilots:
Food security benefited from index insurance as farmers indicated they attained higher yields with the quality seeds (Syroka 2007). Livelihoods also benefited as 1,800 farmers are now credited by financial markets. The agricultural industry also benefited from the addition of the OIBM—a first time agricultural loan provider (Syroka 2007). Overall preference for index insurance is growing and farmer interviews reveal a preference for expansion of land coverage and inclusion of other crops (Hellmuth 2007).

Complications included rainfall measurement errors, seeds that failed to germinate, farmers that sold to traders other than the contracted buyer (NASFAM), and low payouts from long distance between meteorological centers (Hellmuth 2007). The loan for agricultural inputs is based on cultivating one acre of land, though most participating farmers own four acres of land and would like larger loans (Vicarelli; Osgood).

Example of Success

Index Insurance in Ethiopia

In March of 2006 WFP announced a partnership with AXA Re insurance for a national index insurance program for Ethiopia. The index insurance program cost USD $930,000 and provides insurance for 17 million Ethiopian subsistence farmers with up to USD $7.1 million in contingency funds (Lacey 2006). Rainfall is measured by 26 weather stations around Ethiopia (Lacey 2006). This rainfall data is ensured by satellite-based weather forecasting information of MDA Federal Inc. (Lacey 2006). This national program is beneficial because it transfers risk from developing nations like Ethiopia to international risk markets, like insurance markets (WFP News 2006).

In the first phase, from 2004–2006, WFP, the World Bank Commodity Risk Management Group, and the United Kingdom Department for International Development (DFID) started to develop a comprehensive drought-risk financing scheme (Haile 2007). The first phase in demonstrated that Ethiopian rainfall data are accurate and timely enough to allow Ethiopian drought risk to be transferred to international reinsurance markets (Haile 2007).

The second phase of this program aims to scale up the financing package to USD $135 million, comprising contingent funding from bilateral, multilateral and insurance sources (Haile 2007). In early 2007 as part of the second phase, the World Bank approved a USD $175 million safety-net operation for Ethiopia that includes a USD $25 million contingent grant based on the drought index designed by WFP (Haile 2007). Rainfall was sufficient during the 2006 pilot and no payouts were dispersed (Haile 2007).

Projected Success:
Director of Business Planning at WFP Richard Wilcox believes that the Ethiopia index insurance program represent a promising new way of financing aid to natural disasters in developing nations (WFP News 2006). Wilcox said that “We have shown that the reinsurance sector can have an important role to play in effective financing for responses to natural disasters in developing countries” (WFP News 2006). Yale University Professor Robert Schiller also praises index insurance as “a win-win for developed and developing countries (WFP News 2006).

Recommendation 2.2: Rain Gauges & Sowing Calendars for Planning Crop Planting

Overview

The combination of rain gauges and sowing calendars is a low-cost adaptation option for the WFP to address drought-related food insecurity and support the livelihoods and nutrition of populations in West Africa. Rain gauges allow farmers to measure the amount and distribution of rainfall on their land. Sowing calendars inform farmers of the best time to plant and the best crops for the location, based on rain gauge measurements (Hellmuth 2007). Programs to supply rain gauges and sowing calendars will work to lower incidence of crop failure and increase crop yields by providing farmers with vital information about what crops to plant and when to plant.

A rain gauge and sowing calendar program can help rural farmers maintain agricultural productivity despite the variability in precipitation expected as a result of climate change. This program recommendation can be used in any land type, but is most important for locations that are vulnerable to severe drought and unpredictable weather.

Implementation Considerations

Time

The results can be both immediate and long-term depending on the implementation timeframe. If effort is focused on training farmers in a timely manner, farmers will be able to use their knowledge immediately to improve their farming decisions. The program can also offer long-term benefits, as farmers can use the information every growing season, independently of the WFP, once they obtain the knowledge of how to use rain gauges and sowing calendars. This program may take six months to a year to start.

Cost

Rain gauges themselves are low cost tools that are essential to the success of this program. Imported rain gauges range in cost from USD $2 to 10 dollars each. However, if local production of rain gauges can be initiated, as was the case in Mali, gauges can be available at lower costs (Hellmuth 2007). In the initial phases of the program the WFP may consider full or partial subsidies for rain gauges and sowing calendars.

The cost of sowing calendars depends on existence of published sowing calendars or availability of historical precipitation data throughout planting seasons, crop development data, and soil data. If sowing calendars are not published for the West Africa region additional funding and contracting may be needed to gather necessary data and to formulate ideal sowing calendars. One potential source of historical cereal production data is the Food and Agricultural Organization. The FAO has record of historical cereal production for many countries in the West Africa region and crop-specific indicator for rainfall amounts and yields—the Water Requirement Satisfaction Index (WRSI) (FAO).

Meteorological information to improve the use of sowing charts can be phased in gradually. Perhaps the effort to incorporate climate information into the WFP's Vulnerability Analysis and Mapping (VAM) can aid in this process. There is also the potential for transferring support to national governments, as was the case in Mali.

Scale

Rural farmers are the target for rain gauge and sowing chart programs so these activities can be implemented on a community or regional level throughout West Africa. Communication between weather centers and farmers can greatly improve the scheduling of planting too, so involvement of national or regional meteorological organizations will improve success. Also, support by government at all scales will help to standardize methods and facilitate information sharing. (Further details in the "Example of Success" at the end of this recommendation)

Relevancy to WFP

The WFP could support this recommendation through a training and development program, in which farmers receive training on the use of rain gauges and sowing calendars. As crop productivity increases, the WFP may be able to phase out food aid to an area. Once farmers are trained to use these materials they can operate independently of the WFP. It is likely that farmers will pass their knowledge on to others in their community.

Challenges

One challenge are the initial costs involved with the implementation of this program including provision of rain gauges, creation or purchases of sowing calendars, training, and operations associated with meteorological information delivery. It is recommended that the WFP partner with other organizations, as was the case in Mali, to provide these types of instruments and meteorological information to farmers at little or no cost.

A second challenge is the fact that some farmers of this region use traditional indicators to make farming decisions. Traditional indicators include: the moon or the appearance of specific birds or insects (Hellmuth 2007). Farmers use traditional indicators to judge the beginning of rainy seasons, time to till fields, and when and what seed to sow (Hellmuth 2007). Farmers that use these cultural methods of decision-making may be resistant to change and difficult to train. Farmers are often unwilling to risk the use of unfamiliar techniques when they know what to expect from traditional methods. These issues should be considered and addressed in the development of training programs. Incorporation of traditional techniques that are successful can be aided by communication with local farmers during the development of training

Example of Success

Rain Gauge & Sowing Calendar Program in Mali:

A rain gauge and sowing chart program is active in Mali as part of an agrometeorological known as the Centre Régional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle (AGRHYMET), which was activated in 1982 (Hellmuth 2007). Rain gauges and sowing calendars are primary elements of this agrometeorological program. An important addition to this program is climate information from various organizations including International Research Institute for Climate and Society (IRI), World Meteorological Organization, the African Centre of Meteorological Application for Development (ACMAD), the national meteorological service, agricultural extension agents, and farmers (Hellmuth 2007). This meteorological information is delivered to farmers over radio stations, television stations, and paper reports, and is presented as seasonal forecasts, ten-day bulletins during the growing season, and three-day weather forecasts (Hellmuth2007).

After the first year of AGRHYMET it was shown that the fields of farmers that utilized the program had higher yields than those that did not participate (Hellmuth). These higher yields resulted in more participation, growing from 80 farmers in 1990 to over 2,000 in 2007 (Hellmuth 2007). In 2003-2004 crop yields and farmer incomes were again higher where the agrometeorological program was used, most notably with maize, which brought in 80% more income (Hellmuth 2007). Higher yields have increased farmer confidence and investment in higher technology seed, pesticides, and fertilizers, which have increased agricultural production further (Hellmuth 2007).

This program is moving away from being sustained by aid agencies towards national management. In 2001 the Mali government made a financial commitment to strengthen the meteorological service, resulting in the opening of new and improved meteorological buildings in 2004 (Hellmuth). Furthermore, in 2005-2006 the Mali government allocated about USD $1.2 million for new weather stations and equipment (Hellmuth 2007).

Recommendation 2.3: Strategies to Reduce Desertification

Overview

Desertification can be caused by a combination and variety of different factors. Drought has caused additional stress on the biological resources of the Sahel. If resource management is adequate, little permanent damage is caused by droughts. When resource management is inadequate, a drought accentuates adverse impacts and accelerates land degradation. Strategies to combat desertification are unique and should be designed according to the underlying causes, but most desertification can be controlled through altering human activities (Dregne 1986). General measures to adjust non-sustainable activities are summarized in Figure 6.

The activities of land modification mentioned above are the root causes of desertification. Modification of these activities would increase the resiliency of local ecosystems that provide the resources upon which people depend. In West Africa some immediate measures

Figure 6: Reducing Desertification (Williams 1998; Neil 1999)

Causes	Strategies	Notes
Deforestation	**Reforestation** Re-planting trees, especially in shelter belts. Planting grasses can help stabilize the soil and cut down on erosion by wind and rain.	Refer to reforestation recommendation in section 3.1
Over-cultivation	**Land Management Policies** Using good farming practices such as proper crop rotation and the use of manure as a fertilizer	Refer to cropping methods in section 4.1
Overgrazing	It is important that the young trees are fenced off to prevent grazing by animals, and that highly erosive areas are avoided	Refer to reforestation recommendation in section 3.1
Poor Irrigation Systems	**Effective Irrigation Projects** Make sure the water is not evaporated on the surface or lost through transport, which increases its salinity and wastes water	Refer to micro-irrigation recommendation in section 2.5
Drought	Can be increased by deforestation, so reforestation can help to reduce it. Terracing the land to slow down water runoff will make better use of the available rain	Refer to sections 3.1, 2.4, Appendix 1, and Appendix 2

may be put in place to prevent further loss of arable land due to sand movement and the expansion of the Sahel which results from wind erosion (Dregne 1986). As wind erosion contributes the most to sand movement, measures to mitigate wind erosion, such as windbreaks made from trees and bushes, stone stacks around the base of trees, and grooves dug into the ground, should be considered. Due to the economic and development status of many West African countries, a "stone stacks" project is recommended. This type of project requires minimum capital input and increases the resiliency of the land, as well as the ability of communities to reduce desertification.

Implementation Considerations

Financial Considerations

The low cost of "stone stacks" projects is the greatest advantage of this approach compared to other projects. Local availability of the stones or rocks is important, otherwise the cost of transportation and its environmental impact may outweigh the benefits.

Scale Considerations

The scale of the project is very flexible, and the projects can be assigned to households living near desert areas. This type of project could also be incorporated into a large-scale sand-block building project, which could extend to the country or regional level. Projects at this larger scale should be coordinated and managed by regional officers.

Timeframe Considerations

Compared to the measures listed in Figure 6, small projects can be effective in reducing desertification in a shorter time frame (normally in 1-2 years). This project idea should be kept in mind when implementing agricultural and reforestation programs in Sub-Saharan countries, as the stone bunds (described below) are designed to protect plants or grass. By increasing the protection of areas that may be arable, these projects will increase potential agricultural productivity. This is especially the case when such efforts are integrated with effective land management policies.

Relevancy to the WFP

The WFP could implement this project via development programs at local or community levels in regions along deserts. The techniques for these projects are simple and require minimal financial support, except for the supply of grass seeds or tree seedlings. With minimal labor, local residents can easily contribute to the project. In addition to food-for-work, "Seedlings-for-Work" or similar programs could also be effective. The potential economic value of harvesting or producing products from seedlings (or grass) that survive and grow should be noted.

Challenges

There are some factors that may potentially limit the success of this small scale project: 1) It requires a good supply of local stones, as transport of stones from other regions is costly (and increases carbon emissions); 2) Considering the stability of stones, the slopes of the landscape should be no more than 2%, otherwise there might be a safety concern; 3) The planting and growth of vegetation requires a certain level of precipitation and/or irrigation, thus the availability of water should be taken into account.

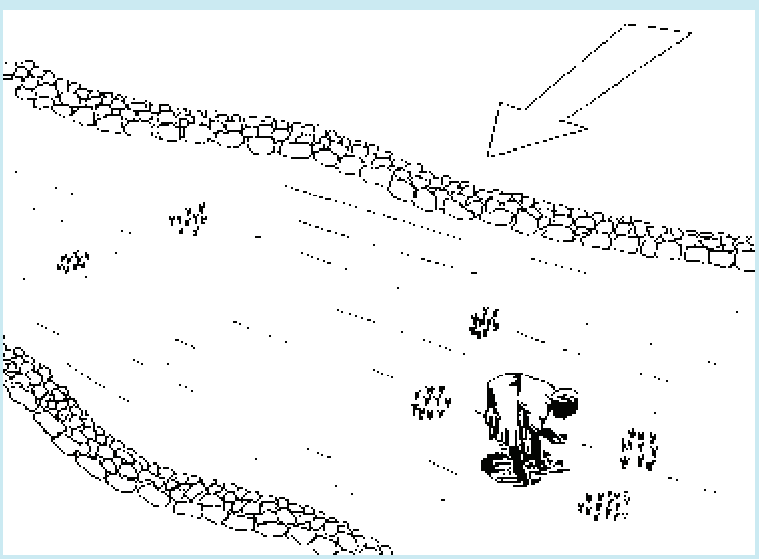
Example of Success

The Agro-forestry Project (PAF) in Burkina Faso

This project idea was adapted from the Agroforestry Project (PAF) initiated in Burkina Faso by FAO (Critchley 1991). It was not specifically designed for treatment of desertification, but rather was a general strategy to extend arable land area. However, as this small-scale strategy requires building stone bunds, which protect the plants against moving sands, it can be used as an option to reduce desertification problems caused by sand expansion.

The Agro-Forestry Project (PAF) of Yatenga Province, Burkina Faso, has earned the reputation of being one of the most successful soil and water conservation projects in sub-Saharan Africa.

Traditionally, simple stone lines had been used to help reduce the risk of sand expansion and erosion in fields, but this practice had largely been forgotten. However, through discussions with the people, PAF saw this as the basis for improved food production. The new design allows the rainfall runoff to spread evenly through the field. When runoff reaches a stone bund, it spreads out and slowly trickles through the small holes between the stones. In addition, organic matter from the catchment area, such as eroded soil, bits of dead plants, and manure, is filtered out of the runoff. This rich sediment builds up behind the bunds and this improves the soil.



(Illustration from Critchley 1991.)

The combination of contour stone bunds and other techniques leads to rapid benefits for farmers. Yields are improved in the first season after the land has been treated, and even in very dry years these techniques ensure some yield. For these reasons the techniques have proved very popular, and by the end of 1989, some 8,000 hectares in over 400 villages had been treated with stone bunds (Critchley 1991).

Recommendation 2.4: Rainwater Storage

Overview

Rainwater harvesting is a simple, low cost, and small-scale supply technology that has been practiced for thousands of years since its origination. It is a convenient way to collect water, particularly when either surface water or ground water sources are not available or are not easily accessible (IFAP, 2005). It involves the collection, storage, and productive utilization of rainwater. In addition, it reduces surface runoff and prevents soil erosion, thereby contributing to environmental conservation (GWP, UNEP). Water harvesting on croplands may be achieved through micro-catchment or macro-catchment systems or through floodwater farming (in situ rain water harvesting). Under micro-catchment systems, runoff is collected close to the crop growing area and is used to water the crops (GWP, UNEP). Macro-catchment systems involve the collection and storage of runoff from large areas via watercourses or pipes. In situ harvesting involves small movements of rainwater as surface runoff in order to concentrate the water where it is wanted, such as roof harvesting techniques (Hatibu).

Implementation Considerations

Factors considered for choosing rainwater harvesting for domestic use include catchment type and size, cost of the harvesting system, family size, length of the drought period, and alternative water sources (GWP, UNEP).

In choosing the type of water harvesting intervention for crop production, several factors are considered, including:

- rainfall amounts and intensities
- evapotranspiration rate
- soil infiltration rate, water holding capacity, fertility, depth
- crop characteristics- water requirements, length of growing period, resistance to waterlogging;
- land topography and hydrology
- socio-economic factors - of population density, priorities, costs of materials, land tenure and regulations governing water resources use (GWP, UNEP)

Effective water harvesting requires community participation, which can be fostered through:

- sensitivity to community needs, culture, indigenous knowledge, local expertise
- full participation in all aspects
- consideration of gender issues
- consideration of the prevailing farming systems
- consideration of national policies and community by-laws (GWP, UNEP).

Relevancy to the WFP

Approximately one third of Africa is suitable for rainwater harvesting. For this reason, it is recommended that rainwater harvesting be used not only for domestic uses, but also for crop irrigation (Black 2006). Rainwater harvesting projects may be integrated into the WFP's development projects in semi-arid and drought-prone areas, as it enhances yields and reliability of crop production. It also conserves soil and prevents flood damage, which can have positive effects on food security.

Challenges

The immediate challenge of rainwater harvesting is assessing various technological options in terms of their technical feasibility, economic viability, social acceptability and environmental sustainability. A cost-benefit analysis should be run, along with integrating knowledge of the local culture, amount of rainfall, climate and land types in order to make a proper recommendation on which rainwater harvesting technique to use.

Example of Success

Rainwater Harvesting in Kenya

According to reports released by the United Nations Environmental Programme (UNEP) and the World Agroforestry Centre, communities and countries suffering or facing water shortages as a result of climate change could dramatically boost supplies by collecting and storing rain through rainwater capture systems (Black 2006). Thus, the UNEP and the World Agroforestry Centre have urged local governments and other stakeholders to invest more widely in rainwater capture systems, a technology that is cost-efficient and simple to deploy and maintain. Unlike big dams that collect and store water over large areas, small-scale rainwater-harvesting projects lose less water to evaporation because the rain or run-off is collected locally and can be stored in a variety of ways. The reports mapped rainwater-harvesting potential of nine countries in Africa: Botswana, Ethiopia, Kenya, Malawi, Mozambique, Uganda, Tanzania, Zambia and Zimbabwe. In addition, similar assessments are underway for Addis Ababa, Dar es Salaam, Kigali, Maputo, Lusaka, Lilongwe and Harare (UNEP 2006). The pilot project that tested these report data in Kisamese, a Kenyan Maasai community located in East Africa, has improved water supplies through building collection and storage facilities. It has also been observed that Maasai women are now spending 4 hours less each day finding and fetching water. Harvesting technologies used in this case include installing containers and mini-reservoirs or "earth pans" (macro-catchment techniques), storing rainwater on roofs (in situ techniques), and digging trenches to help water soak into the soil in the small kitchen gardens that were established as a result of these technologies (micro-catchment techniques) (Hatibu; UNEP 2006). Not all rainwater is captured; one-third goes back into rivers and lakes, but it is estimated that over half a million liters of water has already been stored.

Capture systems help manage water resources more efficiently:
Image: Rainwater Storage Tank (Black 2006)

Recommendation 2.5: Micro-Irrigation

Overview

Micro-irrigation refers to individualized small-scale technologies for lifting, conveying and applying irrigation water. These systems apply water through small devices that deliver water onto the soil surface very near the plant, or below the soil surface directly onto the plant root, at regular and frequent intervals (IMWI 2006). This reduces stress due to moisture fluctuation in the root zone, often resulting in a larger and better quality yield (IMWI 2006). In addition, proper water management can control the timing of the harvest.

Implementation Considerations

Micro-irrigation technologies are increasingly seen as a means of addressing the growing competition for scarce water resources. They can be categorized into two types based on their technical and socioeconomic attributes: low-cost micro-irrigation technologies (which include drip technology, bucket and drum kits, micro sprinklers, and micro tube drip systems) and commercialized, state-of-the-art micro-irrigation systems used in many industrialized nations (IMWI 2006). It is recommended that the low-cost technologies be implemented in the West African region. Appropriate low-cost drip systems have been shown to have positive effects on crop yield, incomes, and food security because they lead to more production per unit of water used. Drip systems have a particular niche in monsoonal climates. They allow farmers to plant earlier so that the crop is already established at the onset of rains, enabling the efficient use of rainwater. This helps to avert a crop loss, by reducing declines in yield that could arise from a dry spell or the early cessation of rain. Institutional support will be very helpful for implementing these systems (IMWI 2006).

Relevancy to the WFP

Improving the reliability of water supply for agriculture is a necessary condition for reducing poverty and malnutrition. Proper irrigation techniques can have a large impact on food security because 30% of West Africa's gross domestic product (GDP) comes from agriculture (IUCN 2004). One of the key advantages of using such technologies is that they help to extend the use of water during times of drought or water scarcity. Micro-irrigation can thus improve livelihood security for poor farmers who are vulnerable to rainfall variability (IMWI 2006).

Challenges

The initial investment and maintenance costs of a micro-irrigation system may be higher than other irrigation methods. As a result, small-scale farmers have been apprehensive in implementing these techniques, and they are more widely used by wealthier farmers. In addition, there are the challenges regarding the availability of micro-irrigation technologies and lack of knowledge in applying these techniques (IMWI 2006). To address these problems, special efforts and additional institutional or governmental support would be required to market cost-appropriate technologies to the poor and smallholder farmers. It should be stressed that, despite the higher initial cost of these systems, farmers can generally recover their initial investment capital within 1 to 3 years due to the high efficiency rate and increased crop yields (IMWI 2006).

Example of Success

Micro-Irrigation Pilot Project in Northern Ghana

Northern Ghana receives about 1016 mm of rain per year, most of which is concentrated in a 3-month period. This weather cycle only allows the production of one rainfed crop of cotton, rice, sorghum, or other grain per year. For the remaining 9 months of the year, farmers do not generally produce crops because they have little experience or access to irrigation methods. Winrock International, a non-profit organization, developed an irrigated agriculture program to improve rural nutrition and increase the incomes of farm families through production of high value crops. They set up demonstration sites where adequate water resources were available, and various types of micro-irrigation equipment were used. Four pilot areas were chosen, which used drip irrigation and treadle pumps for dry season farming. The organization also trained farm leaders in using the technology. March 2004 reports state that rural households have access to an adequate year round supply of water through an increase in the number of sustainable potable water sources, as 53 boreholes have been completed and are in use.

Recommendation Chapter 3:

Deforestation

Deforestation has considerable bearing on the activities of the WFP, as the organization serves areas with large refugee populations where deforestation and the destruction of natural landscapes can have a negative impact on food security. The reduction of forested land in West Africa is an important factor in climate change, as forests sequester carbon dioxide. Strategies that reduce the demand for fuelwood not only help avoid deforestation, but also reduce the negative impact on human health that is caused by exposure to wood smoke.

The following section will provide climate change adaptation and mitigation recommendations that the WFP might use to address deforestation in West Africa. These three recommendations include:

- development of tree nurseries and planting projects
- use of solar cooking technologies
- development of carbon credit pro grams.

Recommendation 3.1: Tree Nurseries and Afforestation or Reforestation Projects

Overview

This program would establish community tree nurseries to grow seedlings that could be sold for income and used for reforestation or afforestation efforts. Reforestation is the restoration of forests that have been cleared, while afforestation is the establishment of new forests in areas that were not previously forested. Education for community leaders and members regarding techniques for nursery and seedling management is an essential component of the program. The selected varieties of trees should be appropriate for the local climate, and the use of local seed sources can reduce costs. Nursery varieties can include a combination of native, exotic and fruit-bearing species.

The selection of species is important because of water requirements and ability to withstand local and changing climate. In general, local species may be more suited to the climate, but there is some debate on this issue associated with the poleward shift of species driven by global climate change. Some reforestation efforts are focusing on drought resistant species, which may not be native, in order to prepare for the effects of rising temperatures. Planting a variety of species reduces the risk of widespread failure from climatic changes, pests or disease.

Tree planting can be combined with agriculture in order to increase yields and secure soils (see section 4.1 on cropping methods for more details on agroforestry). Agroforests have been shown to be a very profitable land use in Cameroon (Gockowski et al. 2001).

Some of the key elements for success include:

- significant community involvement
- rights to manage planted areas and use the tree products
- small and local scale for projects
- planting trees in concentrated areas so they are easier to maintain

The planted seedlings must be cared for during at least the first two years, by protecting them from bush fires and livestock and clearing grass around them (Ripple Africa 2008).

Afforestation or reforestation efforts address many of the impacts associated with global climate change. Increased tree coverage reduces flood potential, increases food and crop security, and increases carbon sequestration and soil retention (Smith and Scherr 2002). Trees can be planted to support agriculture through provision of animal fodder, windbreaks, fencing, and erosion control (Smith and Scherr 2002). Trees are an important aspect of local hydrological processes, increasing the moisture capacity of soil, increasing water retention in the local climate, and tempering the effects of drought (Taylor et al. 2002).

Community tree nurseries and reforestation projects aid in both adaptation to the impacts of climate change, as well as mitigation of contributing factors which enhance it. Reforestation mitigates contributions to climate change by sequestering carbon dioxide and reducing deforestation impacts from the collection of fuelwood, providing a potential source of income through carbon credits (see section 3.3 for more information on carbon credits). Rehabilitation and establishment of forests also enhances a broad range of ecosystem services which increase the resiliency of communities that are dependent on their immediate environment, enabling them to better withstand environmental shocks (Smith and Scherr 2002).

Positive results from these types of adaptation activities can be seen in a short time frame, through more diversified livelihoods, in addition to providing direct sources of income, food, and fuelwood. The benefits will be sustained and will increase with time, as forests mature, community tree nurseries become more established, and management strategies are solidified.

Implementation Considerations

Infrastructure Considerations

Educational needs are moderate, and technical requirements are moderate to low. Required infrastructure is moderate, such as tubes, seeds, and simple planting and maintenance equipment. Some type of communication infrastructure is needed to promote the sale of seedlings and enhance community participation in development of nursery sites and maintenance of planted areas. Market infrastructure needs are low (Smith and Scherr 2002).

Property Rights Considerations

The communities managing the maintenance of seedlings must be somewhat permanent, in order to assure seedlings are cared for until establishment. The nurseries could be located on government or private land. The rights of the community to protect and manage regenerated forests should be clear (Smith and Scherr 2002).

Community Involvement Considerations

An essential component, and the core of the program, is community involvement. This program should be driven by community demand. Educating leaders and demonstrating the results of deforestation and the potential for growing fruit tree crops stimulates community interest (Ripple Africa 2008). The community provides labor at seedling nurseries and maintenance of planted areas. The local government, such as the forestry department, can help with maintenance.

Program Sustainability Considerations

These projects can sustain themselves by providing income through the sale of seedlings to other communities or individual landowners, and also by providing direct food sources, market products, and fuelwood. Also, some of the income from carbon credits can be reinvested to support project continuation. Once the technical capacity is developed and the initial resource needs are met, the communities should be able to manage projects on their own. Funding or support from other NGOs and volunteers could help this process and provide the WFP with an exit.

Relevancy to the WFP

The establishment of community nurseries could be implemented through Food-for-Work, Food-for-Training, or Food-for-Assets types of programs. Nurseries help diversify the livelihoods of community participants, providing an alternative source of income and forested areas serve as a source for products such as consumables, market goods, construction materials, and medicinal resources.

Tree nurseries and reforestation efforts enhance food security through soil and water retention, production of consumables, reducing flood risk to crops, and providing an alternate source of income through carbon credits. Regenerated forests also provide sources of income and food through non-timber forest products (NTFPs) such as construction materials and animal fodder. In a Zimbabwe survey of 29 villages, the poorest 20% of the population earned over one-third of their total income from NTFPs (Cavendish 2000).

Challenges

Some projects have encountered challenges with the management and protection of planted seedlings. It is necessary to train locals or engage regional forestry managers to maintain seedlings until they are established. This requires clearing grass from around the seedlings, providing sufficient water, and protecting them from livestock and bush fires (Ripple Africa 2008). Some afforestation projects in Senegal and Niger have failed because of a lack of irrigation at tree plantations (UNFCCC 2003). Encouraging work at community nurseries may be challenging as well.
To address these challenges it is important to educate community members on management techniques, such as keeping herd animals away from seedlings. By concentrating seedlings together in particular areas they are easier to manage (Ripple Africa 2008). Smaller projects that don't require capital-intensive irrigation methods can avoid some of the challenges experienced in Senegal. Combining tree plantings with other crops makes more efficient use of water resources. Also, designating direct responsibility and defined resources for management of planted seedlings is important for success.

Some of the income earned through carbon credits could be used to compensate a community member for work as a manager. If community members are compensated for their work at the nursery through a portion of revenues from seedling sales or a percentage of the resources that are gathered from replanted areas, this could provide a work incentive. Initial compensation for tree management and nursery work could be achieved through a Food-for-Work or Cash-for-Work program, until the project was developed enough to be more self-sustaining.

Example of Success

The Green Belt Movement of Kenya

The Green Belt Movement (GBM) was founded by Wangari Maathai, who was awarded the 2004 Nobel Peace Prize for her work. The GBM of Kenya has worked for over 30 years to maintain natural resources vital to human health and food security, through tree planting projects. Seedlings are purchased from group nurseries. The first phase of the project lasted from 1977-1997, and tree plantings were mainly conducted through women's groups on farms. Women were also paid per each tree distributed, as compensation for their work as extension specialists to ensure farmers cared for the trees. In 1997 they had planted over 20 million surviving trees.

They have created a 10-step process for establishing tree nurseries:

1. Sensitization and mobilization seminars to spread information on the relevance and importance of tree planting, open to anyone.

2. GBM staff support the registration and formation of interested groups with GBM Kenya, often stemming from women's groups, church groups, farmers, or schools.

3. Registration as members of GBM Kenya is supported by volunteers, initiating communication and follow-up between groups and organization staff.

4. Registered groups are assisted in the establishment of nurseries. Some initial seeds are provided and group members collect seeds from surrounding forests.

5. Seedlings are transplanted to individual containers for distribution. Groups are assisted in submitting monthly reports about the status of the nursery, number of seedlings available and any challenges.

6. Availability of seedlings is announced to the community and those interested are assisted in the preparation of holes for planting. All trees are monitored to ensure planting.

7. Group members check holes to ensure proper size of .61m width and depth.

8. Approved holes receive seedlings. Seedling distribution is recorded in monthly reports. Groups receive a partial payment for seedlings from GBM Kenya as an incentive for work.

9. Groups check seedling survival and proper care after one month and send information to GBM Kenya.

10. Groups check seedlings after three months and if reports are acceptable to the monitors the seedlings are paid for by GBM Kenya.

The first phase was successful because the benefits of tree planting were understood and the skills of raising and planting seedlings were learned.

Purpose	Best suited species	Primarily planted in	Secondarily planted in
Environmental conservation	Indigenous	Public places	Farm but sparsely
Household needs	Exotics (fast growing)	Farms	—
Fodder	Exotics (fast growing)	Farms	—
Medicine/Herbs	Indigenous	Public places	Farms
Food Security	Exotics & Fruit trees	Farms	Public places
Shade	Indigenous	Farms	Public places
Increase Biodiversity	Indigenous (to support birds, animals & plants)	Public places	Farms
Protecting cultural sites	Indigenous	Public places	—

Source: The Green Belt Movement International. http://gbmna.org/w.php?id=13

The second phase is meant to advance environmental awareness by moving tree planting to public lands. Indigenous trees are used and the same 10-step procedure is followed. Simultaneously, individuals and groups continue planting on farms without compensation, and are encouraged to commercialize tree nurseries. Tree planting is expanding to forest catchment areas (watersheds) and riparian reserves. The species of tree is determined by the intended purpose of planting:
Source: The Green Belt Movement International. http://gbmna.org/w.php?id=13

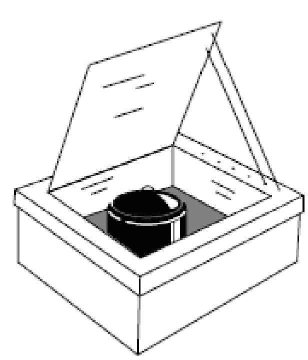
Recommendation 3.2: Use of Solar Cookers as a Substitue for Fuelwood and Charcoal Stoves

Overview

Solar cookers present a positive alternative to wood-based fuel due to the associated deforestation and health concerns. They are devices that cook food using energy from the sun's rays. It is estimated that currently in West Africa wood-based fuel provides more than 90% of household energy needs, and demand for this fuel continues to grow. The United Nations Food and Agriculture Organization (FAO) reports that between the years 1980 and 2000 the consumption of wood for fuel purposes increased in the region from 114 million m3 to 175 million m3 (FAO 2003). The high demand and consumption of wood-based fuel has had considerable consequences on West African forest lands, resulting in the reduction of the region's forested area. Deforestation and high fuelwood demand can be amplified by increasing populations, along with the movement of refugees and internally displaced peoples. The smoke emitted by the burning of wood can also be harmful to health, particularly for those cooking over wood-fueled fires. Exposure to wood smoke can result in asthma attacks, acute bronchitis, and susceptibility to respiratory infections. Long-term exposure can reduce lung function, cause chronic bronchitis and in some cases death (USEPA 2008).

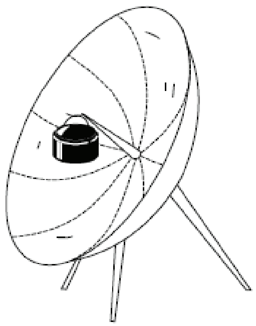
Solar cooking devices are feasible for use in the West African region due to the considerable solar radiation the area receives, and the low costs associated with the construction and use of most solar cooking technologies. These devices require particular materials for construction, and training to understand how to build and use the cookers. There are a few different models of solar cookers that have different equipment and knowledge requirements. The main types of models include the Solar Box, the Panel Cooker, and the Parabolic Cooker.

The Solar Box is a box structure that is made with dark panels and is covered on top with clear glass or plastic. When the box is closed and left in the sun, it heats up and cooks the food inside.



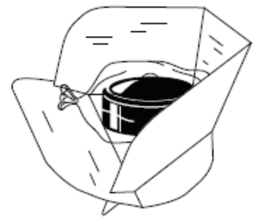
The Solar Box

The Parabolic Cooker is a structure shaped like a curved dish that cooks quickly at high temperatures and can be used in households or larger scale institutional cooking.



The Parabolic Cooker

The Panel Cooker is made of a reflective material that combines structural elements of the Solar Box and the Parabolic Cooker. It is portable and can be left unattended out in the sun to cook food.



The Panel Cooker

(Illustrations from Solar Cooker International 2004)

Implementation Considerations

Type of Cooker	Materials	Cost	Other Considerations
Solar Box	• Wood/Bamboo • Plastic/Glass • Rice hulls or Straw • Reflective Metal • Paint	• USD $40-70	• Reaches about 300° F • May take twice as long to cook as conventional oven • Cooks vegetables, fruits, legumes, grains, most bread • Not hot enough to stir fry or cook flat bread • Used in households
Panel	• Carton board or Woven mat • Reflective material	• USD $3-20 • Assembled cooker can be purchased from Solar Cooker International for USD $25	• Reaches about 300° F • May take twice as long to cook as conventional oven • Cooks vegetables, fruits, legumes, grains, most bread • Not hot enough to stir fry or cook flat bread • Cooks for 5-6 people • Easy to Construct • Requires 10-20 heat resistant bags per year • Can be left unattended
Parabolic	• Sheet Aluminum • Wood/Bamboo • Nuts and Bolts • Rivets and Washers • Tools (drill) • Piping	• USD $70-200+ • prices depend on materials	• Heats quickly, cooks faster • Reaches temperatures between 350-400° F • Can stir-fry • Cooks vegetables, fruits, meats, grains, legumes, bread • High material and technical requirements for construction • Requires adjusting and supervision while cooking • For household and large scale institutional use

(Solar Cooker International 2004)

Cultural Considerations

The solar cookers do not perform in the same manner as the ovens and cooking fires that West African communities are used to. Some cookers are also only able to cook one pot of food at a time, which may prove difficult for larger families. Limitations such as these may require that individuals begin cooking meals earlier and for longer periods of time. Also, it may take some experimentation to understand how traditional foods can be cooked in these devices.

Relevancy to the WFP

Solar cookers can promote the mission of the WFP by provide recipients of food aid with a method of cooking that is low cost and sustainable. As the need for fuelwood would be reduced, the effort spent on gathering fuelwood would decline. The time saved from reduced collection of fuelwood can be dedicated to other productive activities. The WFP has also shown a commitment to addressing health issues, particularly those that pertain to women's health. As it is women who do most of the household cooking they receive considerable exposure to wood smoke that can have adverse affects on health. These solar cooking devices can address these health concerns and support self-sufficient and sustainable livelihoods.

Challenges

One challenge for implementing this recommendation is the material requirements involved in building the solar cookers. The Solar Box and the Parabolic Cooker in particular require quite a few materials that may not be readily available to all the communities where the WFP works. Communities may also not be able to afford the materials to build these types of devices. Some of the cookers also are complex and require significant knowledge in order to construct them. The WFP can resolve these complications by providing pre-assembled cookers or the materials to build cookers. It would also be important to provide recipients of aid with the training needed to build and use the devices.

Other key considerations are the limitations of these cookers and the cultural challenges associated with these cookers, as mentioned above. To overcome this challenge, workshops designed to help people better understand what the cookers are capable of and allow them to experiment would be beneficial. To improve success of a solar cooker program the provision of these solar cookers to communities should be combined with a period of technical support and assistance.

Example of Success

Solar Cookers International in Kenya

In July of 1995 the organization Solar Cookers International began a program in Kenya in which they provided solar cookers to two refugee camps in Kakuma and Dadaab. The organization held workshops in which women were taught how to use the solar cooker (the panel cooker model was used) and were given a solar cooker to take home. In the case of Kakuma the solar cookers were given out for free, along with a ration of food, to those who attended the workshops. In Dadaab those who wished to participate in the workshop and receive a solar cooker had to participate in work projects conducted within the camp such as tree planting or clean up of the area in exchange.

This project was considered a success and by October 1995, 1,500 families had come to the workshops to receive a solar cooker and training on how to use it. Periodic monitoring of the refugee camps showed that women continued to use the cookers. The organization also found that these solar cookers provided women with more time during the day as they did not have to spend as much time searching for and gathering fuelwood as they had in the past (Colby 2006).

Solar Cooker Pilot Program in South Africa

In a study conducted in the northwestern region of South Africa, 70 families were provided with solar cookers for a year and then surveyed to determine how often they used the cookers and how useful they were. They found that before receiving solar cookers on average 50% of meals were cooked using fuelwood, and that after receiving the cookers about 35% of meals were cooked using the solar devices and the amount of meals cooked by wood fuel decreased to 42%. After the study ended participants were given the opportunity to purchase solar cookers, and 51 were sold (Solar Cooking, 2001).

Recommendation 3.3: Carbon Dioxide Emission-Reducing Projects for Carbon Credit Generation

Overview

To address the issue of deforestation within the context of climate change, this program recommendation will propose a combination of strategies. Enhanced cooking stove technologies exist that are more fuel-efficient, have fewer emissions, and can use renewable forms of fuel other than wood. In combining a solar cooker program with the burgeoning markets for carbon credits, it may be possible to also generate revenue from using new cooking stove technologies. With these recommendations the WFP may be able to develop programs that provide opportunities for enhancing community livelihoods, improving food security and reducing threats to the forest resources of West Africa.

Understanding Carbon Credits

Carbon finance uses market-based solutions to fight climate change by funding projects that reduce global greenhouse gas emissions (Labatt 2007). In simple terms, regulatory measures, such as the Kyoto Protocol, give allowances for greenhouse gas emissions that are usually lower than the regulated entity is currently emitting. For example, let's assume country X produced 100 million tons of carbon dioxide (100 MtC). Through the Kyoto Protocol, country X has committed to reducing its emissions by 10% and now they have an allowance of 90 MtC. To meet the reduction commitment, country X needs to either reduce its emissions by 10 MtC, or buy carbon credits worth 10 MtC. Normally they would plan a balanced combination of reductions and credits that made the most economical sense for their situation. Higher demand for carbon credits can increase their price and thus give an incentive to a country to reduce its emissions if mitigation options are cheaper than buying carbon credits. If country X decided to reduce its emission below their allowance to 80 MtC, then they would have a surplus of 10 MtC which they could sell as carbon credits on a carbon trading market.

There are several kinds of carbon markets. Some carbon markets trade carbon credits that can be used to comply with mandatory emission target reductions, such as in the example above. Others are considered private markets for those who are not bound by regulation, but are choosing to voluntarily offset their carbon emissions. This could be a corporation or an individual who has decided to buy carbon credits to offset the carbon dioxide emissions generated by their airline flights, for example. Each market has different types of carbon credits with different prices, and each will have different regulations for how the carbon credits can be created to be sold on the market. For example, a reforestation project in Ghana would have specific regulations or guidelines to follow depending on what kind of carbon credits it would generate. The global carbon market was valued at USD $30 billion in 2006 (Capoor 2007). The majority of that is in the trading of allowance credits with levels around USD $25 billion; the trading of credits that are generated by project-based activities makes up the remaining USD $5 billion.

The Clean Development Mechanism and Africa

The Kyoto Protocol sets emission reduction targets for the European Union and 36 industrialized nations that have ratified the protocol. Industrialized nations are called Annex 1 countries. As of the end of 2007, 137 developing (non-Annex 1) countries have ratified the Kyoto Protocol, but have no obligations for emission reductions. This group includes all of the countries in the WFP West Africa Bureau. The Clean Development Mechanism (CDM) created under the Kyoto Protocol encourages opportunities for sustainable development and low-carbon technology transfer in these developing countries. Under the CDM, developing countries can partner with Annex 1 countries on greenhouse gas emission reduction projects. The carbon credits (called Certified Emission Reductions or CERs) generated as part of these projects can be used by the industrialized countries to comply with their Kyoto Protocol allowance mandates (Labatt 2007). To date, CDM projects have transferred nearly USD $9 billion to developing countries and make up almost all of the project-based carbon credit market (Capoor 2007). The voluntary offset market is estimated at only USD $60 million for 2007 (Hamilton 2007). Most of the CDM projects have occurred in Asian and South American countries, often targeting efficiency and emission reduction opportunities in industrial and power generation processes which produce high volumes of CERs. Many African countries currently do not have highly developed industrial sectors in their economies, and thus only 2.6% of the global CDM projects can be found on the continent today (Capoor 2007). However, it has been recognized that more investment through the CDM needs to occur in Africa, where there is a growing interest in the carbon market. In September of 2008, Senegal will host the new All Africa Carbon Forum, sponsored by the UN Framework Convention on Climate Change (UNFCCC) and the International Emissions Trading Association (IETA). This conference will specifically target capacity development within Africa for participation in CDM projects.

Implementation Considerations

There are significant initial costs that are often taken on by the partner in the industrialized country in order to get a large-scale project successfully developed and approved by the CDM. The partner country has the economic incentive and the capital to finance the project's up-front costs, as well as the costs of ongoing monitoring and verification that are required under the CDM guidelines.

Relevancy to the WFP

There are exciting market opportunities to sell carbon credits. These projects generate carbon credits either by reducing existing emission levels, such as utilizing renewable energy sources like solar cookers, or by providing new carbon sinks that sequester existing atmospheric carbon, such as planting trees as part of a reforestation project.

Each project needs to go through a process of validation, verification and certification to be approved by the CDM. This process gives assurance to potential buyers or traders that the carbon credits generated are verifiable for the life of the project. For example, a potential compliance CER buyer will want to be assured that the project that guarantees credits today with new tree plantings is not going to get cut down tomorrow making their carbon credit investment worthless and fail to meet their compliance regulations. CDM projects have specific standards and approved methodologies to provide projects with the best chances for success. It is common to have an independent third party organization, accredited by the UFCCC, who acts as an intermediary to the CDM process. CDM projects will not provide direct carbon credit revenue to the WFP. However, these mechanisms have the potential for direct financial support to the communities where the WFP is currently engaged in sustainable development programs that increase local livelihoods. The WFP could have a consultative and facilitating role in CDM projects, which would enable the project initiatives to leverage their existing community development efforts.

Challenges

The DCM has rigorous methodologies which their approved projects must adhere to. For the voluntary project market, standards are beginning to evolve. The Climate, Community and Biodiversity Alliance (CCB) has created a set of project design standards specifically for "multiple-benefit land-use climate change mitigation projects." The CCB is a broad global partnership of research institutions, corporations and environmental organizations, with their CCB Standards being well regarded (CCBA 2005). The WFP would likely benefit from cooperation with a partner organization possessing experience in climate change mitigation projects, whether they choose to support CDM or voluntary projects. A partner can help to facilitate the funding needed for project development, assist in project design to meet market standards, and negotiate the contracts for the sale of carbon credits.

While the project standards are high, the transaction costs, in both time and money, to get a CDM project certified have created a barrier to the small-scale non-industrial projects that organizations like the WFP might be involved in. The bundling of several small-scale project activities into one aggregate project is an approach being utilized more frequently. For the CDM, a small-scale project is defined as one that mitigates less than 15,000 tons of carbon dioxide emissions per year (t/CO2e/y). To put that in context, an approved CDM project in Indonesia that bundles the use of 1,000 solar cookers is projected to account for emission reductions of 3,500 t/CO2e/y (CDM 2005). There are several approved CDM methodologies that cover solar cookers and renewable cooking fuel methods. In June 2007, a regional workshop was held in Senegal on improved cooking stoves projects across West Africa (HEDON 2007). Using a bundled approach, the WFP could possibly help facilitate a country-wide alternative cooking fuel program into one CDM project eligible for carbon credits. This same bundling approach could be done for small-scale reforestation projects and conservation agriculture practices conducted through existing WFP development programs.

Example of Success

Energy-Efficient Cooking Stoves in Lesotho

Cooking stoves in the developing world rely predominately on fuel derived from the burning of biomass such wood, charcoal, and animal dung. Many traditional stove designs have been improved to burn biomass more efficiently with fewer emissions. Fewer emissions are not just tied to climate change, but also to reducing negative health effects from breathing stove exhaust. Stoves that burn wood and charcoal more efficiently reduce the demand on timber resources as well as reduce the costs of cooking fuel for families.

A project for the use of more efficient cooking stoves in the African country of Lesotho has been developed by the Programme for Basic Energy and Conservation (ProBEC) in Southern Africa, a program of the German Agency for Technical Cooperation (GTZ), and the WFP. By building on an existing relationship between ProBEC and the WFP's school lunch programs, the introduction of new stoves at 550 schools and orphanages was possible. The new technology, called Rocket Stoves, can reduce the amount of fuel wood needed to cook meals for 100 people by 90%. Local artisans have been trained to build the stoves, which helps to decrease the stove cost and provides needed job skills and employment for the community.

GTZ and their carbon credit partner, Climate Care, developed the methods to aggregate the emission reductions across the 550 project sites and generate carbon credits. Using the sustainable principals of the Clean Development Mechanism, but applying them to the voluntary market, they were able to create a credible market opportunity for selling offsets of 15,000 tons of CO2. The revenue generated by Climate Care and GTZ helps to pay for the implementation of the stove project (Barclays 2007; ProBEC 2008).

Recommendation Chapter 4:

Direct Impacts of Climate Change on Food Security

Success of agricultural yields and food availability will depend directly upon strategies that help farmers adapt to the challenges of climate change that impact food security, such as increasing temperatures, increased evaporation, and higher variability in rainfall. West Africa's dynamic landscape and topography, climate vulnerabilities, and soil types require agricultural practices that are designed specifically to complement local conditions. Maintaining agricultural resources and promoting sustained benefits beyond the present may initially seem challenging. However, these goals are achievable, and critical for sustained food security in the region.

The following recommendations incorporate criteria based upon feasibility, efficiency, sustainability, proven successes, expert opinion, and the general consensus of links between climate change and agriculture. These three recommendations include:

- incorporation of agricultural biodiversity through cropping methods
- fertilizer application
- homestead gardens to improve resiliency and nutrition

Recommendation 4.1: Incoporation of Agricultural Biodiversity Through Cropping Methods

Overview

By the year 2030 the overall population of developing countries is expected to more than double, yet the rural agricultural population is likely to remain constant (Dixon, Gulliver et al. 2001). This implies an increasing ratio of urban to rural residents, highlighting the demands that will be placed on agricultural systems to provide for increased urban populations. As this population dynamic changes, appropriate farming systems will not only be vital to food security in agricultural communities but to the rest of the country, continent, and world (Dixon, Gulliver et al. 2001). Agricultural biodiversity, or agrobiodiversity, is a key and often overlooked component to food security and sustainability (Thrup 2000). Incorporation of practices which promote agrobiodiversity into traditional crops and cropping methods used in the West Africa region is key (Thrup 2000). Increasing the diversity in crops and cropping systems in an agroecosystem can help maintain or replenish agrobiodiversity and the many ecosystem services it provides, such as genetic resources, soil fertility, nutrient cycling, productivity, and pest control (Palm, Sanchez et al. 2007; Thrup 2000). In addition, increasing agrobiodiversity on existing farmlands increases their productivity, reducing the need to convert natural lands for farming use (Thrup 2000).

The following alternatives to monoculture systems are meant to preserve and replenish soil nutrients, prevent soil erosion, maintain soil moisture, increase crop yields, increase pest resistance, and promote food security (Thrup 2000). Traditional crops and cropping methods are being lost around the world and being replaced by 'modern' and 'intensive' varieties and techniques (Wood and Lenne 1995). These diversified cropping systems may involve combinations of crops, livestock, and trees. In recommending these programs, it is essential to incorporate traditional or local crops that are adapted to the climate of the region and thus require lower inputs (Wood and Lenne 1995). Inclusion of local cropping methods and native varieties is vital for the successful implementation of the following cropping methods (Thrup 2000, Dixon 2001). Every crop and method suggested here should be tailored not only to the region and community, but to the farmer as well.

The options for diversified cropping systems include but are not limited to:

• Mixed systems—the integration of a food or cash crop with livestock. They can be agroforestry systems that support livestock grazing, or grain crops that livestock may feed on after harvest. For example, cowpea grains can be grown for food and the crop residue may be used as fodder for livestock (Ortiz and Hartmann 2003).

• Agroforestry—Tree cropping for harvesting of the product of the tree, such as fruits or nuts, rather than for lumber. This may be integrated with natural forest systems (Sanchez 1995).

Ally cropping—a form of agroforestry in which a food or cash crop is grown simultaneously with a tree crop (rows of trees alternating with rows of an annually harvested crop). The annual crop may provide income while the trees mature. Once mature, it is important that the tree and the crop do not compete for nutrients in order to continue production of the crop.

• Crop Rotation—The alternating of two crops, one per growing season. Crop rotations of sorghum with millet or cowpea are common in West Africa (Bagayoko, Buerkert et al. 2000).

• Intercropping—Simultaneously planting two or more crops in adjacent rows. Similar to ally cropping, but not limited to agroforestry projects. Intercropping can be used with millet and groundnut (peanut) (Bagayoko, Mason et al. 1996).

• Aquaculture—Use of croplands for fish farms in times of flood (see section 1.3 on aquaculture for more details.)

As the impacts of climate change in the region become more sever, it will be ever more important to consider the ability of crops to withstand flood and drought. Increasing agrobiodiversity can promote food security in the face of climate change by improving the viability of farming in risk areas. Specifically, in areas that may experience drought the use of cover crops will protect the soil from drying out and from erosion. Enhancing agrobiodiversity can also help to mitigate climate change by increasing storage of biomass in the soils, which sequesters carbon (Tieszen, Tappan et al. 2004). Consideration and employment of local species and varieties is a key requirement for food security in the region (Thrup 2000).

Implementation Considerations

Cultural Considerations

Much can and should be learned by examining the traditional or historical farming practices of a community and the use of native crops (Thrup 2000). Using these resources may be essential for adapting to the future effects of climate change. While in most rural agricultural communities vast monocultures are uncommon, it is important to note that this technique can reduce the long-term viability of land. Monocultures will strip the soils of their nutrients more rapidly than practices based upon diversified cropping methods (Wood and Lenne 1995).

Crop Considerations

Agrobiodiversity can be achieved through use of any of the abovementioned methods, as well as others not referenced in this report. When choosing a cropping method it is important to consider regional specifics such as:

- which crops are grown
- which crops are consumed
- what infrastructure is available to transport goods
- which cultural practices may be

innovative and effective

Establishing this information will help to select the most appropriate crops and cropping methods. The use of drought resistant and water tolerant crop varieties will help ensure crop production in areas that are susceptible to drought or flooding (Dixon, Gulliver et al. 2001). Some of the drought resistant varieties that grow well in Sahelian Africa include sorghum, millet, cowpea and groundnut (peanut) (Leff, Ramankutty et al. 2004). Groundnut is grown especially in Senegal, Guinea, and Guinea-Bissau (Leff, Ramankutty et al. 2004). These crops are already grown in the region, but farmers can increase yields and diversify diets by growing more than one crop in an intercropping or crop rotation system. Water tolerant or water loving crops like rice and maize grow well along West African coastal areas during the rainy seasons, along with secondary crops like cassava (Leff, Ramankutty et al. 2004). The use of crops better adapted to the region, like white maize instead of yellow maize, or improved varieties of African rice instead of Asian, will require the use of fewer inputs.

Climate Considerations

As climatic conditions become more extreme, and if semi-arid locales become more arid, it is wise to avoid the growth of water intensive crops such as rice, maize and soybean in these regions. As temperatures increase, evaporation of soil moisture will also increase. Intercropping with cover crops (typically a legume) in dry areas can help maintain soil moisture and replenish soil organic carbon (Reicosky and Forcella 1998). It is important that the main crop and the cover crop do not compete for nutrients. The use of cover crops during winter months (or the dry season) can also increase soil organic carbon and nitrogen in the soils when biomass is returned to the soil before the rainy season (Reicosky and Forcella 1998). Soil organic carbon plays a vital role not only in nutrient resources for crops, but also in maintaining water, temperature and aeration in the soils(Reicosky and Forcella 1998). Agroforestry systems may work well in arid regions, as the shade from the trees will also help decrease evaporation from the soils (Kiepe and Rao 1994). Ally cropping may be used to earn a profit while the trees are maturing. In areas that experience flooding, cover crops can be used to prevent soil erosion and loss of soil nutrients (Reicosky and Forcella 1998).

Fertility Considerations

One of the biggest constraints to crops is the availability of soil nutrients. When using crop rotation, intercropping, or a mixed system with livestock, nutrients are returned to the soil. One of the crops in a crop rotation or intercropping system should be a legume—legumes fix atmospheric nitrogen into available nitrogen for plant uptake. Examples of legumes in West Africa are cowpea, groundnut (peanut), and acacia (a tree common in the region). The remainder of the plant, the stover, can be returned to the soil to replenish nutrients and maintain soil cover. In a mixed system with cowpea, after the cowpea is harvested for human consumption the stover can be consumed by the livestock that will then return concentrated nutrients to the soil in their manure (Wood and Lenne 1995). However, these organic fertilizer inputs are often not sufficient for maintaining the levels of soil fertility needed in cropping systems (Vanlauwe and Giller 2006). Although diversified cropping systems may require fewer chemical fertilizer inputs, the specific nutrient requirements of the crop may require additional fertilizer application (Vanlauwe and Giller 2006).

Scale Considerations

Implementation will likely be most beneficial on a community level. Agrobiodiversity is already seen in homestead gardening, and we recommend implementing these practices in larger scale crop operations. In rural areas where agriculture is the main source of income, improving the agricultural systems could improve the health and well being of the entire community. Increasing agricultural productivity has repeatedly been shown to be an effective tool for decreasing poverty in highly agricultural economies (Dixon, Gulliver et al. 2001). A higher diversity of available crops is associated an increased variety in nutritional intake within the community (FAO Nutrition 1997; Frison, Cherfas et al. 2004).

Relevancy to the WFP

One of the most significant obstacles to successful agricultural production in rainfed systems is access to seeds and fertilizers. The WFP could make a significant impact by providing access to these resources or investing in seeds and fertilizers for the development of local producers. Holding a training program in communities would be a great way to inform farmers about methods of improving their current cropping systems.

In order for farmers' incomes to increase along with their yields, they need dependable access to markets. In areas where seeds, fertilizer, and training are provided the practice by the WFP of purchasing harvests for market sale or local procurement of food aid is very beneficial.

Challenges

Some limitations to implementing these methods include:

• Nutrient deficient soils when beginning these projects as it takes time to replenish soil nutrients, and the careful application of appropriate fertilizers will be essential for guaranteed successes.

• The intrusion of intensive or monoculture farming practices in the region

• Dependence on rainfed agricultural systems, which face mounting threats from climate change. Planting of crops and fertilizer application will be especially sensitive to unpredictable rainfall.

• Unreliable rainfall is an obvious barrier that is difficult to overcome because the high reliance on rainfed agriculture. As climate predictions and communication networks improve, so too will efficiency and crop success.

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Recommendation 4.2: Homestead Gardening for Resiliency and Nutrition

Overview

A homestead or kitchen garden is a small piece of land containing crops cultivated for exclusive or near-exclusive consumption in the household. In many settings worldwide, homestead gardening has served as a method of providing household foodstuffs. They are a proven strategy to curtail malnutrition, provide environmental education, and improve food security in developing nations (Helen Keller 2001). In addition to these advantages, homestead gardens can foster positive externalities for community members, genetic preservation of crops, and venues for new and improved crop technologies.

Homestead gardens range from simple, small plots supplementing nutrition to larger productions that can bring business and environmental education to families, potentially providing household income through surpluses. Homestead gardens diversify access to water and crops through creative solutions to small-scale resource scarcity, thereby increasing the ability to adapt to climate fluctuations (Drechsel 2007). They serve as natural experiment stations, or points of entry for new technologies in agricultural production and water management. For example, new fertilizers can be experimented with in these gardens. Combining water-catchment tanks for the dry season with these projects can provide both educational and practical uses for the community. Increased access to education and agricultural technology increases the resiliency of communities in the face of climate change. As the success of using improved water-management techniques, crop diversification, soil health-enhancing practices, and other environmentally sustainable systems is proven in homestead gardens, larger agricultural producers may be inspired to adopt these practices as well.

Mounting challenges for rural livelihoods make these simple gardens a powerful strategy for dealing with the changing conditions resulting from increasing temperatures and climate fluctuations. Furthermore, environmental education promoted through these gardens can help individuals to mitigate their own contributions to climate change. Because kitchen gardens are designed to exclusively supply households, food security is reinforced. The studies cited in this section highlight the positive impacts of homestead gardens on food security, for both the participating household and the community at large.

Implementation Considerations

Women and Communities

There are many options for the successful establishment of homestead gardens in West Africa. The first and perhaps most crucial challenge is entry into the community. Community involvement, as opposed to financial support or intricate technologies, has been cited by the FAO as the most important factor for a successful school garden (FAO School Garden 2005). Engaging women through direct cooperation with a fixed agriculture extension specialist (agronomic professional who provides educational resources and programs for farm communities), social worker, or health worker could be the most effective strategy for long-term acceptance of the project. Helen Keller International had great success with kitchen and school gardens in Burkina Faso by using community female social workers to lead the implementation and education components. The gardens can empower women with increased participation in household decision-making and a greater ability to influence child health. The direct influence of women over the crop production provides them with authority of its use. The close involvement of women in their children's' diets has proven to increase child health significantly compared with diets controlled by males (Dasgupta 1995).

Education Considerations

The level of education needed to implement a homestead garden is minimal, since they are essentially alternative expressions of local agricultural knowledge and administrative expertise. However, additional access to agricultural and water management technologies is highly recommended. Homestead gardens can also support food security and community education with very little infrastructural or technical requirements, such as roads or complex irrigation systems, as the inputs and outputs are largely internal.

Scale Considerations

In Nepal, the average kitchen garden was observed to measure between 5.7-7.7% of the family's total land holdings. Gardens can be as small as bags or boxes lining the walls of participating women's homes, and as large as hectares surrounding the home. They can also be equally valuable in urban settings. In Accra, for instance, the informal agricultural sector supplies over 280,000 people living in the city with perishable vegetables such as lettuce and onions (Drechsel 2007).

Cost Considerations

According to the FAO guidebook on creating gardens, the cost can be extremely minimal (FAO School Garden 2005). Many tools can be borrowed, seeds can be saved or bought locally, and organic cultivation can decrease costs for inputs such as fertilizers and pest control. The most expensive items are likely to be storage space for equipment, water-management technologies, and fencing. A source of regular income in addition to initial start-up costs is necessary, in order to maintain the equipment, continue to upgrade technologies, and have access to evolving information.

Funding could be provided for the initial 2 to 3 growing seasons for baseline materials, including fence materials, mini-plows, and other inputs via the WFP, local government agencies, or even a micro-finance system. The micro-financing option may be the best option in terms of increasing women's empowerment and ownership of the project. Starting grants or sponsors, followed by the sale of some items in the garden, can provide for the initial capital, recurring expenses, and incentive to work in the garden.

Relevancy to the WFP

Workshops addressing agricultural concerns like soil fertility and crop diversification have been an essential component of all the homestead projects cited in this proposal. Nutrition education fortifies the connection between agriculture and health, while entrepreneurial training increases women's ability to secure household income with surplus produce. This aspect of homestead gardening projects is especially emphasized as an important element of success by Helen Keller International (Helen Keller 2001). They worked on an organizational level, bringing together participating women for educational workshops, water-resource management, creation of market system strategies for surpluses, and other relevant meetings (Helen Keller 2001). If the WFP were to organize such a project with the village women and community leaders fully involved, the only ties to the WFP following the set-up phase would be via regular support for equipment upgrades and information sharing. These two roles, however, could eventually be taken over by other development-oriented local organizations. The project would likely take three months to organize, and another three months to begin preparation of the land and administrative details of implementation. With efficient coordination between funding agencies and participants, the gardens could begin

to produce within the same season of establishment.

Challenges

Despite the proven advantages of homestead gardens, challenges to implementation do exist. These include good seed and water availability, establishing program evaluation structures, the cultural acceptance of new crops, the costs of tools, reliable access to educational programming, and the limitations of depleted soil. The next section addresses implementation options for each of these challenges.

In Bangladesh, where a homestead gardening program has been successful, village nurseries supply seeds, water accessibility, pest control strategies, fencing, and credit methods (Helen Keller 2001). Other entities that could fill this role include the WFP or local government agencies. Households can create partnerships with a central nursery, participate in seed selection educational programs, or connect with already existing seed-enhancement technologies being utilized in the villages for cash crops.

A homestead gardening project in Burkina Faso had access to wells for water, but worked to plant drought-resistant crops as well in an effort to address the issue of water availability. Connections with existing water-management strategies are ideal for this aspect of the program.

Agricultural extension workers, health workers, and other community workers can provide the crop production, nutrition, and business education workshops. Agricultural workshops could support women in developing effective composting and crop rotation strategies for their gardens. Access to fertilizers via the cash-crop programs already established in communities would also benefit participating women.

In order to create an effective evaluation metric, simple questions can be asked of participating women regarding benefits and challenges of the gardens. Observational data regarding yields and diversity of crops should also be documented for on-going collaboration with nutritional information collected by nutritional extension services.

Although in the program in Burkina Faso, new crops like orange-fleshed sweet potatoes were readily accepted, introducing new foods presents a programmatic challenge (Helen Keller Worldwide. 2001). Options for addressing this type of difficulty are nutrition education workshops for participating women or cooking workshops where children as well as women are able to experiment with the new foods (Sifri, Bendech et al. 2003).

One of the reasons why homestead gardens are so powerful is that they can be adapted to a variety of cultural settings. The foods or herbs grown can and should vary depending on climate as well as cultural identity of the participants. The homestead garden project should simultaneously encourage women to plant diverse crops. This diversity should be designed to specifically provide the micronutrients commonly absent from beneficiaries' diets, which will vary depending on the locale.

A known barrier to success of homestead gardens is misunderstanding. If local residents do not understand or are uninvolved with the development of the project, it can appear as though the gardens are designed to keep community members from developing careers outside of agriculture. This lack of participation can also feed into the idea that gardens facilitate developing nations' dependence on aid. This is why involving residents in the planning and construction of homestead gardens is essential for success. This is also a practical approach, as the expertise of many local adults lies in the effective management of agriculture.

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Example of Success

Widespread Homestead Gardening Projects

Increased production allows for the possibility of marketable surplus. In a joint USAID/OFDA (Office of United States Foreign Disaster Assistance) garden project in Somalia, participating women sell their extra produce, thereby providing funds for other household needs including health care and education costs (USAID 2007). This income is often significant, even if the sum is modest, since it usually represents the only income generated by participating women.

In an experiment in rural South Africa on the impact of homestead gardens on vitamin A levels in children aged 2-5 years old, participating and non-participating households had increased vitamin A levels after one year. Although households with homestead gardens displayed significantly higher vitamin A levels than those not participating, the study explained that the non-participating households' increased levels of vitamin A was due to their consequential consumption of butternut squash as a result of the surplus produced by households with homestead gardens (Faber et al. 2001).

In a study of traditional Nepalese homestead gardens, species richness and homestead gardens were positively correlated. The study found that crop species tend to be preserved in homestead gardens when development threatens species diversity, promoting reliable access to the preservation of genetic diversity of crops (Sunwar et al. 2005). Maintaining genetic diversity of crops increases the resiliency of production systems to threats such as disease and pests.

According to a study on the effectiveness of kitchen gardens in a rural Nepali community, the group participating in a kitchen-gardens program had significantly more knowledge of nutrition (38% versus 13% in the control group knew one of the causes of night-blindness, and 17% versus 3% in the control group knew one of the causes of anemia). Participants were more likely to feed special complementary foods to infants, to preserve food, and to consume higher quantities of 16 types of home-produced micronutrient-rich vegetables and fruits (Jones et al. 2005).

Recommendation 4.3: Fertilizer Application

Overview

Fertilizer application and replacing nutrients in soil can help farmers adapt to the direct and indirect impacts of climate change. The effects of climate change in combination with the current state of degradation of cropland in sub-Sahelian countries may make fertilizer necessary for maintaining productivity. Adaptation to climatic changes using available organic fertilizers will improve conditions in a more immediate timeframe, but inorganic fertilizer use may be required if adaptation measures are aimed at utilizing unproductive or degraded lands (Buerkert and Hiernaux 1998). However, we do not recommend the use of highly marginal lands as these farming systems will be highly unreliable and the costs of inorganic fertilizer may be prohibitive.

Fertilizer complements agricultural production by providing nutrients, securing moisture, and maintaining soil structure. African soils often lack nitrogen, which is one of the three most important nutrients in regional crop development. Overall, any fertilizer application will likely result in increased productivity, but unintended consequences or associated effects of fertilizers are posssible depending on application methods.

Implementation Considerations

The effects of climate change on rainfall and temperature variability may prove detrimental to agriculture if nutrients are not retained in the soil. While many benefits are associated with the use of fertilizers in West Africa, the debate as to the best type of fertilizer to use remains unresolved. Characteristics of the soil moisture and nutrients, as well as crop type and local conditions will influence the choice of which fertilizer and application methods are most appropriate.

Financial and Cultural Considerations

Traditional methods utilizing organic and locally available fertilizers (animal manure and crop residues) are critical and necessary for current agriculture. However, changing environmental conditions may require the modification of traditional techniques to ensure future sustainability (Buerkert and Hiernaux 1998). Solutions are not necessarily simple and information may not be sufficient. For example, nitrogen, phosphorus, and potassium availability are typically cited as the primary concerns in the spatial variability of crops such as millet, however calcium, magnesium, potassium, and sodium, in combination with aluminum, are responsible for the spatial variability in soil fertility (Vanlauwe 2002). Although addressing every specific situation presents a challenge, local nutrient availability can be generally improved through organic fertilizer application. Though chemical fertilizers can offer promising results, without proper management and planning they may have detrimental consequences for cropland, the environment, and public health. In addition, economic considerations regarding the ideal infrastructure for inorganic fertilizers are quite different in comparison to those for organic fertilizers (Matthews 2002).

Regional Considerations

The following three scenarios provide information which should be taken into consideration for programs aimed at improving agricultural productivity and farmer income, using strategies such supplementing deficient soils or improving market access.

I. Low population density, poor market access

Farmers in these regions often use methods that are more land intensive (increased land and decreased labor, fertilizers, and machinery). Farmers may utilize extensive amounts of land because other inputs are harder to locate and market access is low. Farmers in this situation are likely to expand farmland rather than increasing the amount of inputs such as fertilizers. These areas are less likely to accept intensification suggestions and technologies, and other strategies such as improving market access and diversifying crops may be more appropriate for these conditions.

II. High population density, poor market access

In this scenario, farmers have scarce land, labor is abundant, and market access is low. This often results in a decreased use of (and low preference for) purchased inputs. These farmers are likely to be unfamiliar with the application of fertilizer and may require training on its use. Fallow periods decline as land becomes scarce, which often encourages intensification. This situation may promote the perception that it is more beneficial for farmers to hire cheap labor to increase their outputs, rather than using fertilizer to supplement deficient soils.

III. High population density, good marketaccess

Market access allows farmers to be aware of and utilize more advanced options, such as fertilizer. These may be good locations for fertilizer aid as they are experienced with its use and their proximity to the market provides an advantage in achieving economic gains from surplus.

Organic versus Inorganic Fertilizers

Organic fertilizers can be produced from sources such as manure, compost and crop residue. One of the benefits of using crop residue is that it is produced on site, avoiding transportation or distribution costs. The most productive and efficient crops which leave behind the most biomass provide good access to agricultural residues.

The choice between organic or inorganic fertilizers can be difficult and should be determined according to local context and conditions. The following can help to inform an appropriate choice.

• Advantages of organic fertilizer:
There is a relatively low cost to WFP or to the community in need, as transportation costs are mostly eliminated. A less intense input of nutrients may also benefit

the environment by avoiding some of the damage to water quality which can result from inappropriate application of inorganic fertilizers.

• Disadvantages of organic fertilizer:
They are somewhat less predictable in terms of nutrient amounts and nutrient ratios, as compared to inorganic fertilizers.

• Advantages of inorganic fertilizer:
The guarantee of complex nutrient composition allows relatively more predictability.

• Disadvantages of inorganic fertilizer:
The cost of purchasing and transporting these fertilizers is often prohibitive for small farmers. Inappropriate application can cause long-term damages to environmental quality.

Additional Implementation Considerations

It is important to consider that other uses for crop residue that may exist in a locale, which may compete with the use of residue for fertilizer. Often leftover biomass is used for animal fodder, construction, or fire fuel. Promoting techniques which reduce the need for fire fuel, such as efficient stoves or solar cookers (see sections 3.2 and 3.3) can reduce competing demands on crop residue. The benefits of increased agricultural productivity which can be gained through use of crop residue as fertilizer should be weighed against the need for fire fuel.

Relevancy to the WFP

When developing any plans that may be applied to a wide variety of conditions, knowledge of what conditions are similar across areas may help develop a more general solution. During the planning and implementation of activities relating to fertilizer, it is important to consider the makeup of soil, which is a reflection of climate, geology and topography. WFP could serve communities through programs such as food-for-work, where local residents receive aid in exchange for gathering or disseminating this type of information. Training programs which inform farmers on effective fertilizer techniques would also be very beneficial. Establishment of community or homestead composting projects can provide farmers with a dependable and free source of fertilizer. By assisting farmers in developing fertilization techniques which are appropriate for the situation, WFP can increase the self-sufficiency and success of these farmers.

Challenges

The cultural acceptability of different fertilization techniques may pose a barrier to implementing what farmers perceive as novel or risky strategies. Educational opportunities can help to address this challenge, and could be effectively combined with programs such as homestead gardens (see section 4.2). In order to address the challenge of fertilizer costs, these inputs can be provided through bundled loans related to weather index insurance (see section 1.1).

Applied Studies

To illustrate how our program ideas could be effective in West Africa, we have applied recommendations from each Issue Chapter to specific areas within West Africa. The first applied study examines how an aquaculture project in Mali can help communities adapt to increased flooding and even take advantage of it to improve their livelihoods. Second, also looking at Mali, a potential weather index insurance program is explored as a method for adapting to increased drought events. The applied study for deforestation is about a program in Burkina Faso that would incorporate solar cookers and carbon credits. Our final applied study explores using cereal and legume rotations in the West African Sahel to improve food security. These Applied Studies are meant to help translate the program recommendations to the specific context of the West Africa region, and to assist the WFP with implementation.

Applied Study on Flooding: Fish-for-Work in Mali

Overview

Mali is one of the largest countries in West Africa, in both land area (1,241,000 km2) and population (13.1 million) (IRIN 2008), though its population density is relatively low compared with other West African nations. Several land types and climate zones fall within Mali's national borders, from moist sub-humid forest to hyper-arid desert. This diversity makes it an informative location for applied study. Agricultural production is high, particularly in cereal production, with 80% of all national production being rice (Peterson and Kalende 2006). Mali also hosts the largest fishery production in the Sahel and 40% of West Africa's freshwater fishery production comes from the Niger River and tributaries of the Senegal. Between 10-20% of fish production in Mali is exported. The combination of high cereal and fish production makes the country ideal for a Fish-for-Work program that cultivates rice patties with fish. There are three principal fish production zones in Mali: the Central Delta of the Niger River and two artificial lakes—Lake Sélingué and Lake Manantali (Peterson and Kalende 2006). Due to climate change the area within Mali which experiences flooding will expand and these events will likely occur more frequently with greater intensity. These weather patterns may allow aquaculture to be expanded to areas that were previously not viable.

Infrastructure Needs

For this applied study, the areas of Niono, Sikasso and Kadiolo have been selected within Mali, due to interest of local women. All areas are in central Mali, which is prone to flooding. In fishing communities, women are the head of the family. Management of aquaculture production needs to be directed toward women, as they are responsible for 90% of fishing activities in Mali. The above regions, though, have experienced difficulty in implementing past aquaculture projects. Mopti may be a better location to begin a pilot program for the World Food Programme. Mopti marks the confluence of the Niger and Bani Rivers and lies within the Central Delta, where in the month of October flood waters can cover over 20,000 km2. It is estimated that this floodplain produces an estimated 70,000 to 150,000 tons of fish per year (Peterson and Kalende 2006). A study between 1996-2002 by the FAO Special Programme for Food Security highlighted the area as having high potential for success with NGO support (Peterson and Kalende 2006).

The Fish-for-Work program administered by the World Food Programme would help to support local livelihoods. There would need to be an educational component to work with local farmers in developing a community management strategy and technical skills. These skills would include assembling appropriate nets or fences to section off areas for aquaculture, stocking fingerlings (juvenile fish) and smoking fish once harvested. In West Africa, food spoilage is a serious concern. To combat this, fish smoking is common in Mali. As aquaculture is extended to other areas of West Africa, education on smoking techniques and storage should be considered integral to implementation.

In addition to using floodplains, irrigation systems can be used for aquaculture. However, these systems can be very expensive. According to the FAO, Mali has the necessary resources to develop such systems (Peterson and Kalende 2006).

Project Cost Estimates

The start-up costs of aquaculture are the primary constraint in developing a successful system. These include costs of procurement of the initial nets to section off the area for operation, added fingerlings (wild native varieties are widely available in Mali), and costs of labor to build the physical infrastructure, run the operation and harvest products. Feed materials for fish may also be considered. These typically consist of agricultural by-products, such as rice bran, cotton waste and fishmeal—all widely available in Mali. Additionally, as spoilage is a concern for fish harvests, the minimal costs of smoking should be considered. Currently, in Mali, most fishing nets are purchased from Korea, Japan and India. Local fishing net production from materials such as bamboo will reduce these costs, and natural vegetation can also be used to secure aquaculture areas (Peterson and Kalende 2006).

To consider the operation costs of aquaculture, there may be some benefit in turning to other African case studies for examples. In a cost and returns analysis conducted in Madagascar, for

instance, revenue from concurrent rice-fish cultivation was higher per hectare than that for either rice or fish, at USD $1,746.90/ha, while total costs amounted to USD $1,174.49, and included both variable and fixed costs. Variable costs included such items as lime (USD $0.67/ha), organic and inorganic fertilizers (USD $164.32/ha and USD $149.58/ha respectively), fingerlings (USD $133.33/ha), rice seeds (USD $22.11/ha), fish feed (USD $54.77/ha) and hired labor (USD $267.83/ha). Fixed costs included depreciation of materials (USD $235.85/ha) and a land tax (USD $10.72). After accounting for all costs, profits amounted to USD $572.41/ha with rice-fish cultivation (Brugere 2006). These prices should be comparable to operating similar operations in Mali with similar inputs.

There are many commercial fish available in Mali. Recent aquaculture operations have focused on tilapia, which sell for CFAF 100/kg, Clarias spp. and Heterotis spp., which both sell for CFAF 600/kg. Catfish, however, may be of interest in some areas. Two African species, Lates spp., which sells for CFAF 2,000/kg, and Hydrocynus spp., which sells for CFAF 1,500/kg, are among the species being considered. Additionally, dried catfish can be sold for as much as CFAF 3-4,000/kg (Peterson and Kalende 2006; Brugere 2006). In Mali local producers are often subject to a fish quality certification tax of CFAF 7.50/kg (Peterson and Kalende 2006).

Challenges

The main challenges to aquaculture programs include start-up costs and lack of credit to obtain start-up inputs, maintaining live fish populations should floodwaters recede prematurely, and spoilage of fish catches. To overcome these barriers, communal management structures may be employed to share the costs. Structural mitigation projects can be established to create refuge for fish during times of drought or reduced water levels. Smoking fish can be incorporated into harvesting to better preserve catches. Though rice-fish production is practiced traditionally in some areas of Mali, education and training programs in these areas may be needed to ensure successful project execution.

Applied Study on Drought & Desertification: Weather Index Insurance in Mali

Overview

Mali suffers from high levels of poverty and undernourishment. As of 2002, approximately 64% of the population lived below the poverty line and 28% were undernourished (Hellmuth 2007). A large portion of Mali is classified as desert or semi-desert, rain-fed agriculture is predominant, and there are frequent drought events (Hellmuth 2007). Index insurance can be a means to provide financial support for farmers when crops fail from low rainfall. Index insurance programs require several inputs, including meteorological entities, a crop and precipitation index, national or local financial institutions, privately owned lands with potential for rain-fed crops, and some subsidy support. Considering these requirements, Mali is an ideal country for an index insurance program since it has a high level of undernourishment, large amounts of rain-fed agriculture, a national meteorological service (Direction Nationale de la Meteorolgie), and Centre Régional de Formation et d'Application en Agrométéorologie et Hydrologie Opérationnelle (AGRHYMET).

AGRHYMET was established in 1975 by the United Nations Development Program, World Meteorological Organization, Food and Agricultural Organization of the United Nations, and nine West African countries as an organization to address food security, desertification control, and water management through training and delivering agrometeorological information (meteorological information that relates to agriculture) to rural farmers (Hellmuth 2007). Many of the elements that support the agrometeorology program of Mali can be utilized in an index insurance program, including: meteorological entities, rainfall and crop yield data, and organizations that provide financial support. An index insurance program will further decrease drought-related risk for farmers by insuring an income source in seasons of drought (Hellmuth 2007). Index insurance policies with bundle loans provides credit for farmers to invest in new technologies (World Development Report 2008: Agriculture for Development). Therefore, an index insurance program for Mali which reduces risk for farmers and encourages investment in technologies such as fertilizer and quality seeds (Hellmuth 2007), can ultimately increase overall food production and thus enhance livelihoods.

Infrastructure

Meteorological Entities

In the early 1980s an agrometeorology project was created in Mali. Over the years the agrometeorology program has utilized climate information from Mali's national meteorological service (DNM), World Meteorological Organization (WMO), International Research Institute for Climate and Society (IRI), the African Centre of Meteorological Application for Development (ACMAD), rural development and agricultural extension agents, and farmers (Hellmuth 2007). This climate-based farming advice is delivered via seasonal forecasts, daily to 3-day weather forecasts, and 10-day bulletins (Hellmuth 2007). Forecasts and bulletins are circulated to farmers over radio, television, and through printed media (Hellmuth 2007).

Climate information for Mali is also collected from various other sources, including Satellite-based precipitation estimates can be combined with local monitoring stations for better predictability of seasonal rainfall. The predictability of the El Niño Southern Oscillation (ENSO) up to a year in advance enables consideration of the weather effects of this phenomenon in the development of insurance contracts (Vicarelli, unpub.).

Required Data

Indices are based on historical and spatial records of rainfall and crop yields. Since its formation in 1982, AGRHYMET has compiled information on both climate and agricultural yields from various organizations (Hellmuth 2007). This climate and agricultural yield data can serve as the basis for establishment of indices for various regions of Mali. Another resource for crop/weather index information is the FAO's Water Requirement Satisfaction Index (WRSI) (FAO 2008).

Financial Institutions

National, regional, or local financial institutions of Mali can provide loans to support this insurance program. Participation by multiple institutions is ideal because it encourages competition between each institution, prompting competitive rates. Some potential lending banks of Mali include: Development Bank of Mali, Central Bank of African States, International Bank for Mali, Malian Bank for Credit and Deposits, and National Bank of Agriculture Development (Banks 2008).

Cost Considerations

Index insurance contracts with bundled loans are an attractive option, as the loans cover the insurance policies and allow farmers to purchase agricultural inputs (e.g. seeds and fertilizer) with credit (Syroka 2007). Index insurance programs may need financial support initially, but will become more self-sustaining in the long-run, as farmers pay for the full financial cost of the program (Osgood). For this reason, banks also benefit from index insurance by expanding their lending portfolios (Syroka 2007).

The World Bank's 2008 World Development Report recommends subsidy support for index insurance to cover the start-up costs for farmers (World Bank 2007). Cooperative financial support from international aid agencies like the World Food Programme, the World Bank, or the Inter American Development Bank is necessary for the initiation of index insurance programs in developing nations (Syroka 2007). Subsidies are also recommended for the continued costs of meteorological data collection and contract design (Osgood). One possible source of this subsidy assistance is Mali's Federal Government, specifically the Ministry of Agriculture. In 2005-2006 the Mali government allocated about USD $1.2 million for new weather stations and equipment (Hellmuth 2007).

Challenges

One of the biggest potential challenges of index insurance in Mali is the fact that 65% of the country is desert or semi-arid, less than 4% of land is farmed, and farmlands are subject to frequent droughts (Hellmuth 2007). The aridity of the land and frequent droughts make farming a high-risk endeavor (Hellmuth 2007). Frequent droughts may deter local banks from providing loans and insurance companies from insuring weather risks.

Mali's climate information-based farming program has driven better farming management decisions and has ultimately resulted in higher yields and incomes (Hellmuth 2007). Index insurance will complement this agrometeorological program and protect farmers from losses associated with drought.

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Applied Study on Deforestation: Solar Cookers and Carbon Credits in Burkina Faso

Overview

This applied study suggests the implementation of a program that would utilize solar cookers in Burkina Faso to take advantage of carbon credit opportunities. A similar approach was used in the Lesotho biomass cooker program described earlier (see section 3.3).

Burkina Faso is ranked 176 out of the 177 countries on the 2007 UN Human Development Report (UNDP 2007), making this one of the poorest countries in the world. 70% of the population survives on less than USD $2 per day. A rapidly increasing population, combined with advancing desertification, is putting an ever-increasing strain on the country's existing natural resources. According to the FAO, 90-98% of household energy consumption in Africa is generated by fuelwood, which is predominantly used for cooking (Amous 1999). Alternatives to wood fueled cooking, such as solar cookers, can have a positive impact on reducing deforestation and carbon emissions. A 2004 study in Burkina Faso looked at how much a family would use solar cookers if one were made available to them. It was determined that the cookers would have a positive impact on reducing a family's use of wood, charcoal and gas (Hermann-Sanou 2006).

Implementation

Through implementation of this type of project, the WFP would provide parabolic solar cookers to 1000 families in Burkina Faso. This country is one of the least urbanized in West Africa, though rapid urban population growth has been occurring in the two main cities of Ouagadougou and Bobo Dioulasso. The latter is situated in a mountainous region in the southwest of the country, consisting of a collection of 30 or more villages where urban agriculture is practiced. Bobo Dioulasso has been selected for this applied study based on previous solar cooker successes there (Hermann-Sanou 2006). However, similar success has been documented in the north of the country as well, and a wide spread application to multiple cities is a worthy consideration. The "Papillon" parabolic style solar cooker has been previously tested on a small scale in this and other areas of Burkina Faso with some success (Hermann-Sanou 2006). This solar cooker is recommended for this project because it is locally manufactured in the capital of Ouagadougou and has been proven successful. A similar solar cooker is being used in an approved CDM project in Ache, Indonesia (CDM 2005). Information is not currently available with detailed emissions reduction calculations for the "Papillon". So, this applied study will use the Indonesian cooker methodology to provide a hypothetical estimate of the emissions reductions and carbon credit potential for a similar solar cooker project implemented in Burkina Faso.

Cost Considerations

In 2004 the unit cost of the "Papillon" cooker was FCFA 50,000 (78 Euros). The WFP or the carbon credit partner could subsidize a portion, or all, of the cooker costs. There would be administrative and travel costs associated with the initial training and dissemination of the solar cookers. WFP may provide training or partner with a local NGO help cover the cost of training families on the proper use of the cookers. The costs associated with certifying, monitoring, and verifying the project for carbon credits would be borne by the carbon credit specialist partner who would own the credits.

Potential Emissions Reductions

To get an estimate of the emissions reductions and carbon credit potential of a solar cooker project in Burkina Faso, a similar project will be used as an example. In Aceh, Indonesia a comparable parabolic reflector solar cooker is being used for an approved CDM project. Each individual cooker generates 600 watts of power and its use as a substitute for fuelwood avoids the generation of 3.5 tons of carbon dioxide (CO2) emissions per year. The Aceh project also distributed 1000 cookers for an annual abatement of CO2 by 3500 tons. With a project life of 12 years the Aceh program can generate a total of 42,000 CERs over the credit period.

The average price of the project-based Certified Emissions Reductions (CERs) is around USD $8, totaling an estimated USD $336,000 of gross revenue. The amount of net revenue that could be made available to the community is highly dependent on the expenses, details of the project and prices that are negotiated with the carbon credit partner. WFP implementation of such a project could occur through a voluntary market project like the Lesotho project (see section 3.3), or it could be a CDM project like the Aceh project. As discussed prior in this report, CDM projects have a higher standard of methodological rigor, making the transaction costs and the price of CERs higher. The market for voluntary credits (VERs) is small but growing, and the projects can often get implemented faster than occurs through the CDM (Kollmuss 2008).

Challenges

As described in the solar cooker recommendation section (see section 3.2), there are some technical and cultural issues that can impede the adoption of alternative cooking stoves in West Africa. As a fuel source, solar cookers are a much more sustainable alternative to the traditional fuelwood and charcoal cooking stoves. However, there have been design advances that provide improved fuel efficiency and reduce emissions of fuelwood cooking stoves. The sale of higher efficiency wood fueled stoves, like those used in the Lesotho project (section 3.3), has been successful in Burkina Faso (Feldmann 2007a). These more traditional stoves could compete with the adoption of alternate technologies like solar stoves.

The performance of the solar stove and reduced fuel costs can help to overcome some of the cultural challenges. Studies have shown that when properly trained, 76% of families will use the solar cooker daily depending on weather, and 55% of families continue to use it in the rainy season (Hermann-Sanou 2006). Another challenge is that a cooker does not supplant all use of existing wood, charcoal or gas cooking methods. Studies show that it will be used to make rice and sauces, but is still not favored for making corn or millet mush due to heating capacity. However, the cooker can be used for heating water to cook mush. Because mush is a principal meal in Burkina Faso, this may be a particular challenge for the project.

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Applied Study on Food Security: Cereal and Legume Rotations in the West African Sahel

Overview

When identifying appropriate cropping techniques to increase agrobiodiversity, it is important to thoroughly consider issues such as culture, climate, nutrition, soil health, and pests. The combination of existing difficulties in growing conditions in the semi-arid Sahelian areas of West Africa, together with future climate uncertainties, may require an intensified use of acclimatized traditional crops, as well as technological improvements of these varieties. In this section, we consider the cultural, environmental, and nutritional benefits of cereal-legume crop rotations as a possible method of adapting to and mitigating the effects of global climate change. We have found that the benefits of using crop rotation of a cereal and legume are extensive, from significantly decreasing the amount of inputs required to obtain higher yields, to an enhancement of soil fertility, to numerous nutritional advantages achieved through these combinations.

There are several possible crop rotation combinations appropriate for use in the Sahel. These include traditional cereals such as millet and sorghum, as well as legumes like groundnut and cowpea. Many studies have shown that combinations of these cereals and legumes in rotation are beneficial to cereal yields and increase available nitrogen in the soil (Bagayoko, Buerkert et al. 2000; Bationo, Traore et al. 2003; Bado, Bationo et al. 2006). Traditionally, periods of fallow are used to replenish soil fertility for growing these cereals. However, with the increasing need for food, fallow periods have become shorter and less frequent. Rotating cereals with legumes is a viable and environmentally sustainable method of alleviating the growing impacts of continual land use.

Cultural Appropriateness

Millet, cowpeas, sorghum, and groundnuts have been grown in West Africa for centuries. Sorghum is believed to have derived from Ethiopia and spread to West Africa, starting with the Mande people in northern Niger. Millet has West African origins as well, with varieties from tropical West Africa, Uganda, and the highlands (FAO Nutrition 1995). In general, these crops are grown for household subsistence rather than for sale at market (Dixon and Gulliver et al. 2001). Those who do participate in the market often revert to planting traditional varieties when new varieties, subsidies, or other agricultural inputs are unavailable (Dixon and Gulliver et al. 2001).

A connection with traditional crops does not detract from farmers' innate interest in and commitment to technological advances in agriculture. In 1994, for instance, the international development organization CARE facilitated an aid program called the Livingston Food Security Project in Zambia to increase food security of small-scale farmers. Their strategy for accomplishing this goal was to supply early-maturing and drought-resistant seeds of traditional crops in concert with agricultural extension services. Within two seasons, participation in the program expanded from 330 farmers to 6,800 farmers. This result illustrates the significant potential that introducing new technologies married with traditional crop varieties can have on food security in West Africa. (FAO Community 2001).

Climate Appropriateness

Sorghum, groundnut, cowpea, and millet are all well adapted to a variety of climate conditions, especially in locations where maize is harder to cultivate. In general, Sorghum requires 400-600mm rainfall per season. Dakar is an example of an area that receives approximately 500mm rainfall annually (FAO 1983). Millet has been known to grow in very drought-prone areas with depleted soils, needing between 200-600mm of rainfall (FAO Nutrition 1995). As an example of this type of climate, Agades in Niger is an area that receives 175mm average annual rainfall (FAO 1983). The Spanish variety of groundnut is best suited for West African regions that receive less than 500mm of rainfall annually. In areas with more than 500mm of rainfall per year, the Virginia variety of groundnut is more suitable (Shankarappa 1997). Cowpea can tolerate drought better than many common beans. Some data suggests that the most viable land for millet and sorghum cultivation today is in the Sudan-Guinean area (FAO Nutrition 1995).

Another advantage of each of these crops is that they all have a wide variety of uses. Sorghum, for instance, can be used for flat bread, porridge, beer, and sweeteners. Parts of the plant can also supply fuel, dye for leather, and fiber for baskets or fish traps.

Nutritional Appropriateness

In addition to the cultural advantages of the aforementioned crops, they each have considerable nutritional value. Cowpea, for instance, contains significant levels of vitamin B and important minerals (CGIAR 2005). Cowpea also complements dairy protein because it contains the amino acids lysine and tryptophan, while lacking methionin and cystine (Bressani 1985).

Groundnuts provide a number of important macro and micro nutrients, including vitamins E, K, and B, especially B1 or thiamine. The niacin content of groundnuts balances cereals, which are often lacking in this nutrient (CGIAR 2005).

Sorghum and millet have similar amounts of protein to those found in wheat and maize, are high in iron, phosphorous, and B complex vitamins, and (depending on the variety of millet) contain significant levels of calcium (FAO Nutrition 1995).

Applicability and Experimental Examples of Success

The benefits of cereal rotation with a legume are well accepted, and reach beyond human nutritional and cultural value. This cropping system has proved to enhance the resiliency of crops to weather fluctuations, pest infestations, and other threats to food security. This section will address the environmental advantages of cereal-legume crop rotations, and illustrate successful cases with examples from West Africa. Two experimental studies in Sahelian West Africa examined millet-cowpea rotations and sorghum-groundnut rotations for their effects on soil fertility and crop yields.

Soil fertility

One of the major gains from cereal-legume rotation the fixation of nitrogen in the soil. Studies show that there are higher levels of available nitrogen for cereals which are planted after legumes than after fertilizer application alone (Bagayoko, Buerkert et al. 2000). Legumes fix nitrogen by taking it from the atmosphere and transforming it into a plant-available form in the soil. The process has the subsequent potential to reduce amounts of fertilizer needed for soils, thus reducing costs for the farmer. Because many farmers in West Africa struggle to afford the purchase of sufficient inputs for production, this decrease in costs could be immensely beneficial to the food security of these communities. Fertilizer application alone may provide similar increases in yield, costs can be prohibitive for many farmers.

All cropping techniques in this study were found to mine the soil of nutrients (Bagayoko, Mason et al. 1996). Fertilizer application of superphosphate, rockphosphate, cereal crop residues, and calcium ammonium nitrate were applied at various stages of growth aiming to supplement the nutrients made available through the rotation (Bagayoko, Buerkert et al. 2000). In 2000, Bationo et al. suggested, that a legume-millet rotation with 30 kg of nitrogen added per hectare would be the most viable option for millet in the Sahel. With cereal-legume crop rotation, chemical fertilizers may be used as supplements.

Yields

In a region of primarily rain-fed agriculture, any improvements to soil health can significantly improve yields. Crop rotation may enhance yields by altering the physical and microbial properties of the soil, as well as reducing pest problems (Bagayoko, Mason et al. 1996). These results were quantified in a study conducted in Nigeria and Burkina Faso in 1996 using crop rotation of an improved millet variety and a local cowpea variety. When millet was planted where cowpea had been planted the previous year, yields increased by17% to 30% (Bagayoko, Mason et al. 1996). In this study, with limited fertilizer inputs, soil nutrients and nitrogen levels also increased. Hand weeding in conjunction with a mild application of pesticides to control thrips (an insect that may transmit microbial pathogens) mitigated the threats of pests.

This same study intercropped pearl millet with cowpea and found that seasonal crop rotation systems had higher yields overall than intercropping systems (Bagayoko, Mason et al. 1996). Yields of cereal following cultivation of legumes were as much as 24% higher for millet, but varied by year and location, possibly due to rainfall variations. Again, there was no significant increase in the legume yields. This may be due to rain variability. The study also found that rotations increased soil levels of mineral nitrogen at all sites (Bagayoko, Buerkert et al. 2000). The use of rotation was observed to increase early mycorrhizal establishment, providing a beneficial symbiotic fungi that enables extended nutrient uptake for plant growth.

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In the studies cited here, Sorghum-cowpea, sorghum-groundnut, and millet-cowpea rotations all proved to be successful combinations (Bagayoko, Buerkert et al. 2000). The use of sorghum-groundnut and millet-cowpea rotations in semi-arid regions could increase crop yields, increase the availability of nitrogen in the soil, lower spending on fertilizer and improve plant interactions with soil biota.

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Conclusion

West Africa is very diverse, both geographically and culturally. In delivering food aid to these 18 countries, the West African Bureau of the WFP maintains a broad range of programs in this logistically and politically challenging terrain. To meet designated aid targets, which include supporting local livelihoods and responding to emergency situations involving displaced populations, the WFP is susceptible to fluctuations in the international food commodity market, as well as in the viability of local agricultural production. The recent trends in rising food prices highlight these poignant challenges as substantial concerns. Climate change will likely exacerbate losses caused by drought or extreme weather fluctuations, which will impact both local and international markets. Though all nations are at risk of the impacts of climate change, West Africa is particularly vulnerable to such fluctuations both biophysically and economically. This region currently lacks the institutional, resource and infrastructural adaptive capacity which enables more developed countries to better manage these impacts. Periodic droughts and floods are obstacles to reducing poverty and hunger in developing counties; current climate change predictions may inflate these obstacles.

In this report, we have presented recommendations to address four major vulnerabilities in West Africa, including flooding, drought and desertification, deforestation and direct impacts of climate change on food security. The latter focal area is impacted by many factors, but we have addressed it separately to highlight a few specific agricultural approaches to improving food security. Most populations in West Africa are dependent on rain-fed agricultural production or external food aid. Local food production is a key element in enhancing food security to serve both communities and WFP distribution of aid. Each program recommendation may differ depending on the locale of implementation. For instance, in the northern parts of the West Africa region there are concerns over water availability, while the southern coast may be concerned with rising sea levels that have the potential to displace populations or lead to salt-water intrusion in highly productive agricultural areas.

Flooding is common during the rainy season in West Africa. Climate predictions suggest increases in storm severity and sea-level rise in some regions, leaving coastal, flood plain or deltaic communities at risk. Our recommendations include proactive solutions such as structural management, sea level preparedness and management plans, and aquaculture production in flood plains. The latter applied study is a means to locally produce a high-protein food that can be cultivated along with rice production. This technique can be used to reclaim lands that may be typically unusable for other agricultural production during the rainy season. These recommendations may lead to higher area nutrition, increased local incomes and community-managed control systems for improving livelihoods.

Drought and desertification is a major concern within West Africa. The Sahel has been a primary region of concern over roughly the past 30 years because of long periods of drought. Desertification is closely linked with periods of drought. In this report, we highlight recommendations including weather-based index insurance, rain-gauge and sowing chart introduction and improved water usage through such means as rainwater storage and micro-irrigation. Weather-based index insurance was the focus of our applied study, which has great potential in West Africa for improving farmer livelihoods by reducing risk in seasons of low precipitation. As climate change leads to greater regional variability in rainfall, reducing risk for farmers in low rain seasons is central in encouraging local food production. Such plans should be considered on a national or international scale to disperse risk, rather than implementation through local financial institutions.

Deforestation is often the result of unsustainable land practices. Our recommendations focus on reduced deforestation, as well as encouraging reforestation and afforestation. Our applied study focused on carbon credit programs. These types of programs are gaining international acceptance and support and can be successful in protecting existing forest resources in West Africa, in addition to supplementing local incomes through forest stewardship and plantings. We developed this recommendation out of concern that deforestation in West Africa often results from fuelwood collection, as well as the important links between forests and food production. Forests and woodlands around refugee camp operations may be particularly vulnerable. Other associated recommendations include supporting tree nurseries and use and/or distribution of solar cookers. Both provide a means to increase availability of tree stocks. Solar cookers encourage alternative cooking methods that do not involve fuelwood collection, also reducing the effort spent on wood collection.

The program recommendations that we examined in this report describe the links between particular vulnerabilities and food security. We also explored the direct impacts of climate change on food security. Our recommendations included cropping methods that can be employed to directly improve agricultural biodiversity and increase yields. Our applied study focused on cereal and legume rotations, which improves soil fertility and crop production. Culturally appropriate crop choices will need to be considered in these programs, and education about other crops may be needed as temperatures increase and climate change shifts growing regions and seasons. Additionally, in this report we examined homestead gardening as a viable way to reduce food aid dependency and improve community nutrition through participatory education.

As weather-related shocks increase demands on food aid, including access to food as well as transportation costs, the WFP should be aware of alternative actions that may help specific regions adapt to a changing climate. The program recommendations outlined in this report may fit into existing WFP program areas or may be new areas of focus. In either case, incorporating environmental education for WFP staff, community members and other stakeholders will improve the effectiveness of WFP in achieving their mission. The appendices of this report also provide additional ideas and resources for further investigation, as well as potential partnerships on the local, national and international level. These recommendations, combined with anticipated incorporation of climate change factors into the WFP's Vulnerability Assessment Mapping (VAM), should help to alleviate concerns over the inherently unpredictable elements of climate change. Increased monitoring and vulnerability modeling should be considered as a means to further develop response mechanisms to climate change in West Africa.

While the WFP has the logistical infrastructure to provide short-term critical food needs and humanitarian relief, long-term community-based food assistance and training programs will be necessary for adaptation and mitigation efforts to manage climate change in West Africa. Though our program recommendations specifically address the four vulnerabilities that we identified, a combination of programs and approaches will likely be the best solution. Many of these activities are already in practice in West Africa, but implementation of such recommendations on multiple fronts will improve the effectiveness of strategies for adapting to climate change. In addition, knowledge sharing between institutions, governments and local communities presents a vital channel for climate change preparedness.

It has been a great honor to prepare this report for the WFP and we very much appreciate the opportunity to work with an organization that has such a direct and lasting impact on communities in need.

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Appendix I: Additional Program Ideas

This appendix contains information that the WFP may want to explore further in order to develop additional programs related to climate change mitigation and adaptation. Because of time constraints we were not able to provide a more detailed analysis of these ideas. However, we hope this information will be a useful starting point for the WFP.

Flooding

Weather Index Insurance

Typical weather index insurance programs insure farmers against drought, but it may be considered for flood-prone areas as well. Precipitation beyond a certain threshold, and subsequent runoff, can damage crops at different stages in maturation, as can too little rain. The primary limitation of weather index insurance for flood protection is that additional weather monitoring stations would be required to ensure accuracy. There would need to be a greater density of stations to apply this idea to flooding, or satellite imaging (e.g. the Normalized Difference Vegetation Index, NDVI), could supplement local monitoring data.

Drought

Clay pot water filtration

This is a new technology that allows water filters to be made from commonly available materials and locally produced using cow manure as the source of heat, without the need for a kiln. The filters have been tested and shown to remove common pathogens such as e-coli. The production of these filters is quite simple. The working principle is based on pores in the filter that are wide enough for water droplets to pass through, but too narrow for pathogens.
http://info.anu.edu.au/ovc/Media/_pdf/ClayPotFilter_final_web.pdf

Micro Dams

Micro dams are simple earth filled dams that store rainwater and surface water underground without evaporative losses. They are constructed with low-permeability rock that traps water behind the structure (IFAP, 2005). Large-scale underwater mining may not be feasible in West Africa, but small yield, near surface groundwater is present. Ttraditional allocation techniques can be very useful, and if properly maintained, micro dams could sustain a small community's water needs for both agricultural and domestic uses (IFAP, 2005). One of these alternatives to more costly irrigation techonolgy is the foggara system, a complex network of vertical shafts dug into a sloping plateau above an oasis (IFAP 2005).

Groundwater Lifting Boreholes

Water-lifting technologies in West Africa are limited due to technical, economic and social constraints. However, digging a low cost, small-scale borehole that lifts groundwater in relatively low volumes (often tens of meters) can provide communities with greater water access (Snell 2004).

Greenhouse Technologies for Arid Farming

Greenhouse technologies allow for the control of evapotranspiration from vegetation and climate conditions such as moisture, temperature, and solar energy. These conditions are controlled by greenhouse materials, energy inputs, and water inputs, allowing greenhouses to provide optimum growing conditions in the semi-arid and arid regions of West Africa. The different input technologies for greenhouse materials, energy, and water come in a range of costs.

Information on useful greenhouse technologies, such as the desert greenhouse, can be found at www.desertgreenhouse.com. This company offers two technologies for greenhouses, the plastic/glass greenhouse and the closed desert greenhouse ("Desert Greenhouse"). For comparison, the average open field farming operation produces 5 kg/m3 and has water demands 100 liter/kg of production ("Desert Greenhouse"). The farming production with a plastic/glass greenhouse is 20-30 kg/m3 and a has a water demand of 30 liter/kg ("Desert Greenhouse"). Farming production with the closed desert greenhouse produces 60-90 kg/m3 and has a water demand of 5 liter/kg ("Desert Greenhouse").

A second example is the Seawater Greenhouses of The Royal Society at: http://royalsociety.org/page.asp?id=1496&printer=1.
"The Seawater Greenhouse offers a possible affordable and sustainable means of providing food without reliance on large inputs of fresh water or energy" ("Dr. Philip Davies - Turning the Desert Green"). The Seawater Greenhouse is in prototype stages, but is a promising option.

A success story of greenhouse agriculture is found in one of West Africa's driest regions—Cape Verde, which averages less than 75mm of rain per year (Hamilton). Farmer Emilio Lobo has built a greenhouse to grow hydroponic produce (Hamilton). With this technology he uses half of the water of traditional agricultural farming methods (Hamilton).

The Zai System in Mali: Micro-catchment technique called "pitting"

Practiced mainly in Mali, Burkina Faso and Niger, where it is known as "tassa", zai is a traditional technique for conserving water and rehabilitating degraded land. The Zai system consists of a series of man-made pits or holes dug on abandoned or unused land, dug approximately 80cm apart to a depth of 5-15cm and with a diameter of 15-50cm. The holes capture runoff precipitation, because the land is typically less permeable to water. The zai pits are filled with organic matter so that moisture can be trapped and stored more easily, and are then planted with annual crops such as millet or sorghum. The zai pits extend the favorable conditions for soil infiltration after runoff events, and they are beneficial during storms when there is too much water.

The compost and organic matter in the pits absorbs excess water and acts as a form of water storage for the planted crops. However, this can also be a disadvantage of the system if they become waterlogged during extremely wet years. No special equipment or knowledge is needed to adopt the technology, and the cost of implementation is mainly calculated according to the farmer's opportunity cost of time. The maintenance of the pits does require the farmer to invest additional time for activities such as deepening and refilling the pits. However, the economic return to the investment is close 100% because the land brought under production had been abandoned or unused. The success of zai planting pits has been documented in many parts of the Sahel region. In 1989-1990, a project implemented by the Djenné Agricultural Systems Project (SAD) showed that agricultural yields increased by over 1000 kg/hectare compared to traditionally plowed control plots (IFAP 2005).

Climate Change Mitigation

Beluga SkySails

Large towing kites that cut fuel use on cargo ships. WFP may want to consider this technology for reducing the emissions for transportation of food aid. http://www.skysails.info/

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Appendix II: Potential Partnerships

Many of the recommendations made throughout the report would benefit through cooperation with other entities. Some important organizations are mentioned in the body of the report, but the additional partners listed below may be considered by the WFP in order to increase effectiveness and efficiency when implementing programs.

Flooding

1. Direction Nationale de l'Aménagement et de l'Equipement Rural (DNAER) (Mali)

2. Food and Agricultural Organization (FAO) of the United Nations' Special Program for Food Security

3. United States Agency for International Development's (USAID) Famine Early Warning Systems Network (FEWS NET)

4. Worldfish Center

5. Kenya Red Cross Society

Deforestation

1. The Burkina Faso solar cooker study was done in conjunction with a project organized and funded by ACCEDES (Christian Alliance for Economic Assistance and Social Development).

2. In Lesotho, the Programme for Basic Energy and Conservation in Southern Africa (ProBEC) partnered with Climate Care Trust Ltd to assist with the carbon credit generation and trading aspect of the efficient cooking stove project.

3. WFP has now engaged EcoSecurities to assess its opportunities to for carbon credits, and this might be an excellent opportunity to fully utilize the alliance.

4. The nonprofit organization RIPPLE Africa has been conducting a tree nursery and planting project in the Nkhata Bay District of Malawi. They have worked closely with the District Forestry Office and roughly 400 village headmen. www.rippleafrica.org

Appendix III: Supplemental Resources

This appendix contains references and resources to further develop program recommendations and provide the WFP with information that will be useful for addressing climate change.

Internet Resources

1. World Agroforestry Centre's Website: www.worldagroforestry.org

2. Winrock International: www.Winrock.org
Winrock International is a nonprofit that seeks to increase economic opportunity, sustain natural resources, and protect the environment. They provide access to new technologies for local individuals and communities, promoting long-term productivity, equity, and responsible resource management that assists those living in poverty around the world.

3. Iroko Foundation, www.Irokofoundation.org, an NGO which supports community forestry and community conservation initiatives that protect Africa's forests, wildlife and forest based livelihoods.

4. Vegetative Barriers:
Vegetative Barriers for Erosion Control, USDA-NRCS Kika de la Garza Plant Materials Center, 1999. USDA-NRCS Kika de la Garza Plant Materials Center, Kingsville, Texas. 20p. (ID#1452) www.plant-materials.nrcs.usda.gov/pubs/stpmcbr1452.pdf

5. West Africa Rice Development Association, "Consortium formed to rapidly disseminate New Rice for Africa":
www.warda.org/warda1/main/newsrelease/newsrel-consortiumapr01.htm

Journal Articles

P.J.M. Cooper, J. Dimes, K.P.C. Rao, B. Shapiro, B. Shiferaw, and S. Twomlow. "Coping better with current climatic variability in the rain-fed farming systems of sub-Saharan Africa: An essential first step in adapting to future climate change?" Agriculture, Ecosystems and Environment 2008. vol. 126 pp. 24–35.
doi:10.1016/j.agee.2008.01.007

- Discusses challenges associated with improved agriculture in sub-Saharan Africa in light of uncertainties related to global climate change. Relates the importance of increasing the coping abilities of farmers to manage predicted constraints. Describes the availability of new tools which link climate variability to agricultural impact and discusses risk management strategies.

Mark W. Rosegrant, Sarah A. Cline. "Global Food Security: Challenges and Policies."Science 12 December 2003: Vol. 302. no. 5652, pp. 1917 – 1919.
DOI: 10.1126/science.1092958
http://www.sciencemag.org/cgi/reprint/302/5652/1917.pdf

- General review of the many factors which combine to influence food security, such as: climate change, HIV/AIDS, water scarcity and declining investment in agriculture, crop varieties and biotech in Africa. Includes projections of food supply/ demand, importance of education, water harvesting projects in Africa, and agroecological approaches. Also has links to other resources.

Jules Pretty.“Can Sustainable Agriculture Feed Africa? New Evidence on Progress, Processes and Impacts.” Environment, Development and Sustainability. Volume 1, Numbers 3-4 / September, 1999.
Link: http://www.springerlink.com/content/x262607675472631/fulltext.pdf

- This article is a good resource for applying sustainable agriculture in Africa. Lists typology of eight improvements for agriculture from economic, to scientific, to social spheres. Analysis of 45 programs, in 17 African countries. Shows productivity increases with the accumulation of a combination of natural, social and human capital and notes the importance of participatory processes. “A 50–100% increase in basic grain yields is clearly possible with sustainable agriculture.” Threats: lack of ownership/security, civil conflict, institutional inertia, backlash, economic declines, climate change.

Steven Haggblade. “Building successful partnerships for African agriculture”. Sustainable Development International. Sustainability and Agriculture Issue. www.sustdev.org
Link:www.ifpri.org/events/conferences/2003/120103/papers/papers.htm.

- Discussion of institutional cooperation to promote agricultural success, case study of cassava in W. Africa involving International Institute of Tropical Agriculture, and others. Key issues are good governance (appropriate budgeting and support of farmers in policy) and funding for agricultural research and extension.

More resources:

Luuk Zonneveld. “Shopping for a better life in Africa – Fairtrade helps African farmers beat poverty”. Sustainable Development International. Sustainability and Agriculture Issue.
Link: http://www.sustdev.org/index.php?Itemid=66&section=6&section_name=Agriculture+%26+Biodiversity

- UN FAO is promoting establishment of fairtrade practices in West Africa, which could help reach Millenium Goals. Fairtrade helps farmers adapt to globalization. Cooperative farmers unions that are involved and invested support greater community and social interests. Fairtrade Labeling Organizations International (FLO) is the umbrella for worldwide and national organizations.

M. N. Tchamba. “History and present status of the human/elephant conflict in the Waza-Logone region, Cameroon, West Africa.” Biological Conservation. 75:1; 35-41. 1996. Link: http://www.sciencedirect.com/science?_ob=MImg&_imagekey=B6V5X-3WBY0DS-4-1&_cdi=5798&_user=18704&_orig=search&_coverDate=12%2F31%2F1996&_