



Adapting dryland agriculture in Mali to climate change

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Summary

Agricultural production in Mali is divided into subsistence oriented and rain-fed production of millet and sorghum and commercially oriented production of cotton and rice. Most of the investments in Malian agriculture have been allocated to cotton and rice production while much less emphasis has been given to the development of the dryland crops pearl millet and sorghum. There has been an increase in yield for the commercially oriented crops whereas there has been no increase in the yield of major cereal crops millet and sorghum for the last 40 years. This report focus on how to increase the productivity of these crops and at the same adapt rain-fed agriculture in Mali to climate change.

The temperatures are expected to increase in the Sahel by 1- 2,75 C ° up to 2030 (Hadley Center). High temperatures are already constraining cereal production in Mali. The predictions for rainfall are more uncertain. Some climatic models predict drier weather conditions whereas other models predict more rain. In a recent report by the Ministry of Environment in Mali, it is stated that temperatures will increase, rainfall will decrease and more droughts will occur (STP 2008). A survey on drought probability and the effects of drought have recently been undertaken in all tropical farming systems of the world and the result showed that the millet/sorghum system in the Sahel is one of the most drought prone areas in the world and stunting of children as a result of inadequate nutrition is widespread (Hyman et al. 2008).

Subsistence oriented agriculture in Mali is characterized by cultivation of food crops, use of fallow, limited use of organic input, no use of chemical fertilisers and traditional animal fattening for the Islamic holidays. Productivity is low and grain yields are in the range of 300 to 500 kg/ha. Crop failures are common and farmers often have to re-sow their crops. Food production is frequently constrained by rainfall, but availability of plant nutrients is an equally important factor.

A process for developing a more integrated and more stable agricultural production system has recently been described by Aune and Bationo (2008). Agricultural intensification is here described as climbing a ladder (see figure). The first step on this ladder is to make better use of agricultural technologies that are without any costs to the farmers. This includes technologies like better use of organic fertilisers, water harvesting and pre-germination of seeds. Another approach for improving yield without any cost to farmers is to encourage them to protect the trees that are the most valuable to them. The next step on the ladder is to use very small amounts of mineral fertiliser (microfertilisation). Millet yields have more than doubled through this approach. More advanced farmers can furthermore initiate agroforestry systems based on different fruit trees and Acacia species that can provide animal fodder and windshed. It is unlikely that subsistence oriented farmers can move directly to the highest level on the ladder as each step represents the foundation for climbing to the next. The necessity for labour and institutional support increases as farmers climb the ladder. Such an intensification process must therefore be backed by political and financial support. This intensification process can make dryland agriculture in Mali more productive and less vulnerable to climate change because the crop establishment will be more easy, more water will be stored in the soil and the farming system will be more diversified.

Future Norwegian development assistance to Mali related to adaptation to climate change should align with Mali's National Action Plan on Climate Change. A possible future focus area could be to develop a research and development programme with the objective to make dryland agriculture in Mali more productive and robust to climate change. Such a programme will furthermore build more diversified livelihoods and improve fodder production in Mali thereby minimize potential conflicts between farmers and pastoralists. Institute d'Economie Rural could be the leading actor in Mali. The program can furthermore draw on the NGO network of the Dryland Coordination Group in Mali. Such a programme can possibly be implemented in the regions of Segou and Mopti.

1. Socio-economic conditions in Mali

The population in Mali is estimated to be 12 million in 2008. Approximately 80% of population is currently engaged in primary production and agriculture represents about 50% of the Gross Domestic Product. Economic growth in Mali has been good in recent years and average growth in the period 2003-06 was 5.3% per year (World Bank 2008). Major growth sectors have been gold mining, transport and telecommunications services. Gross Domestic Product per capita has increased from US\$ 240 in 1994 to US\$ 380 in 2005. Despite this growth, poverty in Mali is widespread with about 50% of the population living below the poverty line.

The food production index per capita shows a declining trend over the last decades and about 29% of the population is estimated to be undernourished (FAO stat 2008) (Figure1) . Poverty is not equally distributed in Mali. It is most severe in rural areas as 76% of the rural population is considered to be poor whereas urban poverty is estimated to be 30% (PRSP 2002). The regions also differ with regard to severity of poverty. Sikasso, a region in the south, has lower incidences of severe poverty than the central and northern regions. Mopti is the region with the highest level of severe poverty as 38% of the population fall in this category. The highest extent of poverty is found in the regions Mopti, Timbouctou and Segou. Northern regions such as Kidal and Gao have relatively few in the severe poverty category, but many in the poor categories. The geographical position of the regions is shown in Figure 2.

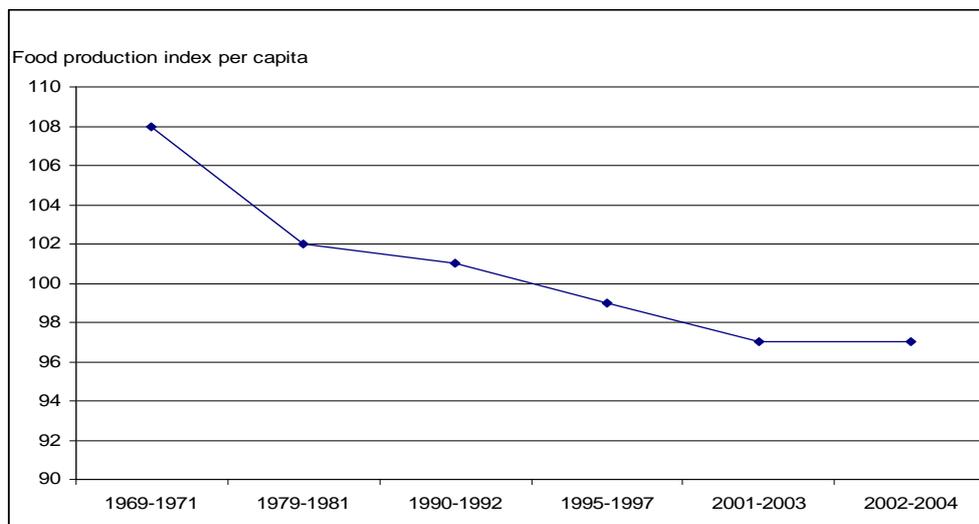


Figure 1. Trends in the food production index per capita in the period 1970 to 2004 (FAOstat).

2. Agriculture in Mali

Mali has ample access to land, but only 14% of the land can be used for agricultural production. The rest is too dry to be used for agricultural production.

Agricultural production is divided into subsistence oriented and rain-fed production of millet and sorghum and commercially oriented production of cotton and rice. Cotton is the most important export commodity. The production is concentrated in the southern regions Sikasso



Figure 2. The regions in Mali

and Koulikoro. Cotton production is rain-fed whereas rice production is based on irrigation with water from the Niger river. Most of the investments in Malian agriculture have been allocated to cotton and rice production while much less emphasis has been given to the development of the dryland crops pearl millet and sorghum.

The areas under all the major agricultural crops have been expanding. The areas with millet and rice have doubled since 1960 while the area with cotton has increased approximately ten fold during this period. The situation with regard to the yield trends differs between the commercially oriented crops and the subsistence crops (Fig. 3). For the latter, the yields have remained more or less the same during the last 45 years, whereas rice yield has more than doubled (FAOstat). For cotton, the lint yield has increased from below 100 kg/ha to an average yield above 400 kg/ha. The increase in yields for the commercially oriented crops is related to agricultural extension, access to inputs like fertiliser and guaranteed prices (for cotton) and assured market. Cotton production in Mali has been organised through the parastatal CMDT. CMDT has controlled cotton production by providing input to cotton producers, purchasing monopoly and guaranteeing prices. CMDT is now undergoing a privatisation process.

Rice production has been supported through de *Office du Niger*. The institution has focused on improving access to irrigation, agricultural extension, credit and institutional development. Major donors such as the World Bank and the governments of France, Germany and the Netherlands have been supporting the *Office du Niger*.

Livestock production has also expanded (Figs. 4, 5). Meat production has increased from about 7,000 tonnes in 1961 to about 25,000 tonnes in 2005. During the same period the number of heads of cattle and goats has tripled.

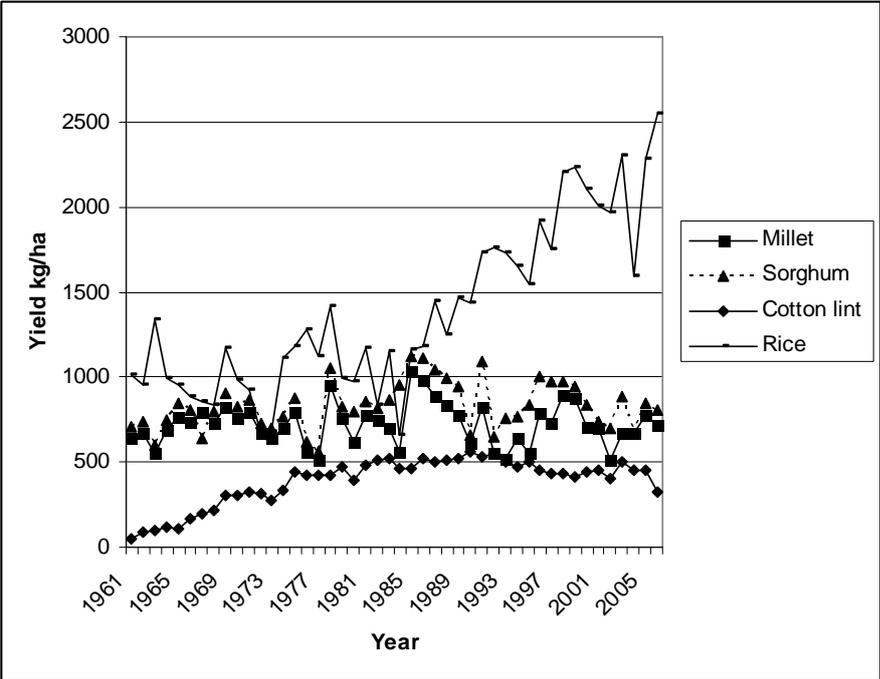


Figure 3. Trends in yields of millet, sorghum, cotton and rice in the period 1961 to 2005 (FAOstat)

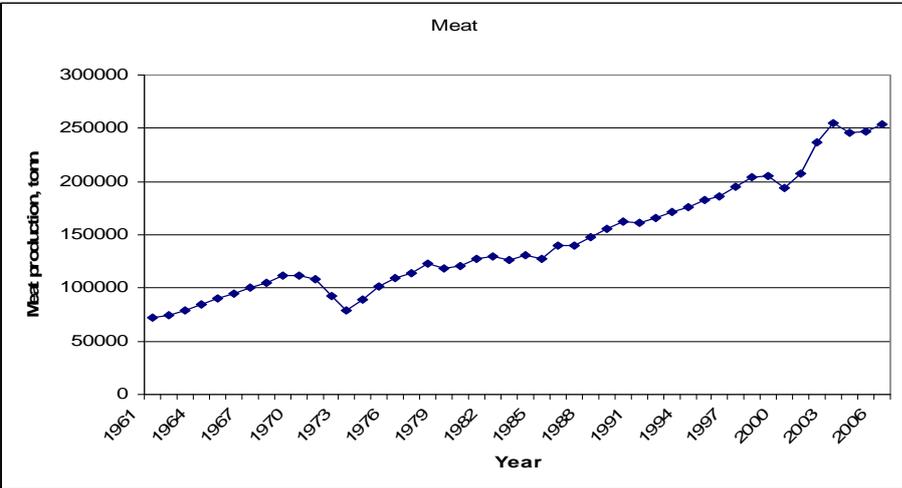


Figure 4. Trends in meat production in Mali in the period from 1961 to 2006 (FAOstat)

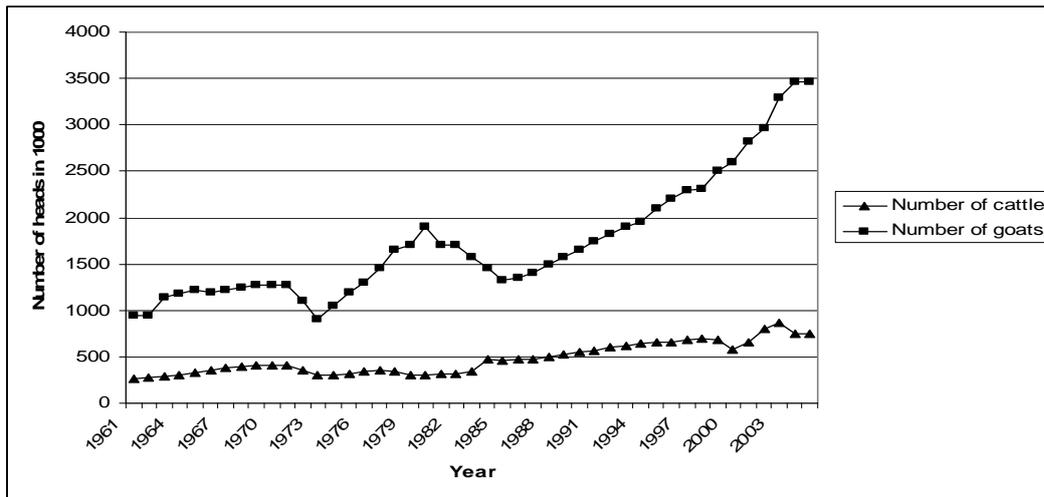


Figure 5. Trends in number of livestock in the 1961 to 2006 (FAOstat)

3. Projection for climate change in Mali and how climate influences land management in the drylands

Rainfall in the Sahel has varied throughout the centuries. In the period 1905-2005 a drying of the Sahel has been observed (IPCC 2007). However, there have been periods with above average rainfall as in the 1950s and periods of droughts as in the 1970s and 1980s. Recent years have been relatively humid in the Sahel. Precipitation is governed by the African monsoon which again is related to sea surface temperatures in the southern hemisphere. The droughts that have occurred in the Sahel are not primarily caused by human mismanagement related to overgrazing, cutting of trees, etc (IPCC 2007), but rather to changes in the surface sea temperatures. Future projections for rainfall in the Sahel are uncertain (IPCC 2007). According to a multi-model analysis the Sahel will get drier, whereas other models show that it will get more humid (IPCC 2007). With regard to soil moisture, no major changes are expected. However, there is a general consensus that the Sahel will get hotter as a result of global warming. The Hadley Centre in the U.K. has estimated that temperatures in the Sahel will have increased by 1- 2,75 °C in 2030 as compared to current temperatures (Butt et al. 2006). The Sahel is expected to heat up more than the rest of the globe because in-land areas will become warmer than the temperature over the oceans. Temperatures in the Sahel are already close to maximum for plant growth, particularly at the beginning of the season. An experiment with different levels of shading showed that temperatures have a pronounced effect on millet production in the Sahel (Vandenbeldt and Williams 1992). In a recent report by the Ministry of Environment in Mali, it is stated that temperatures will increase, rainfall will decrease and more droughts will occur (STP 2008).

A study by Butt et al. 2003 showed that cereal production in Mali would decrease by 15-19% as a result of reduced precipitation and food prices would double. This would increase the number of poor people in Mali. However, such a model must be interpreted with caution since the climatic predictions for Mali are uncertain. What this result however tells, is that decreased grain production can have severe consequences for poverty in Mali.

Land-users (pastoralists and farmers) have over the centuries developed adaptation mechanisms to deal with drought and other calamities. Drought is not an extraordinary event in the Sahel, but rather a natural part of the ecosystem. The land users in the Sahel are to some extent adapted to climatic variations. The adaptation or livelihood strategies can be divided into three main strategies: diversification of the land use system; off-farm income generation activities; and migration (Herrmann and Hutchinson 2005). Land users in the Sahel typically use all three strategies depending on the severity of the situation.

Our understanding of dryland ecosystems has important bearings on policies to improve livelihoods in the Sahel. There has been a heated debate in the last decades between the non-equilibrium school and the carrying capacity school (Herrmann and Hutchinson 2005). The non-equilibrium school claims that the Sahelian environment is never in balance, but changes from year to year mainly due to changes in rainfall. Overgrazing and other human mismanagement are not considered as causes of environmental degradation. The carrying capacity school argues that livestock should be managed in such a way that the carrying capacity is not exceeded. The carrying capacity school furthermore sees environmental degradation as a result of poverty and human mismanagement. Top-down planning has often been associated with the carrying-capacity school whereas the non-equilibrium school has emphasised local participation and flexible management. The carrying capacity school has previously strongly influenced the UNCCD, but UNCCD has in recent years adopted some of the thinking of the non-equilibrium school. The non-equilibrium school generally enjoys stronger research support in the Sahel than the carrying-capacity school.

A survey on drought probability and the effects of drought have recently been undertaken in all tropical farming systems of the world and the result showed that the millet/sorghum system in the Sahel is one of the most drought prone areas in the world and stunting of children as a result of inadequate nutrition is widespread (Hyman et al. 2008). Targeting these areas for development assistance can therefore increase the Sahelian countries' adaptation to drought and reduce poverty.

4. The history of Norwegian involvement in Mali

Norwegian involvement in Mali resulted from the drought that hit the Sahelian region in 1983/1984. Mali was one of the countries seriously affected by this drought. In order to respond to the humanitarian situation, the government of Norway initiated the Sahel-Sudan-Ethiopia programme (SSE). One billion Norwegian kroner were allocated to development assistance to the region over a five-year period starting in 1985. Half of these funds were channelled through the UN system and the rest through bilateral channels, mainly NGOs. The countries that benefitted from this programme were Mali, Sudan, Ethiopia, and later Eritrea. The SSE programme was extended until 1996. Norwegian NGOs that were funded through the SSE programme in Mali were Norwegian Church Aid's programme in Gourma (northern Mali), a Strømme Foundation programme in Bafaloubé (western Mali) and CARE projects in the regions of Mopti and Timbouctou. The SSE programme also funded a large research programme initiated by the University of Oslo. This research focused on food security and pastoral issues. Many Norwegian researchers gained research experience in Mali through this programme and some of these researchers have continued working in Mali.

Norwegian NGOs have continued their activities in Mali since the end of the SSE programme. Norwegian Church Aid (NCA) has phased out its activities in Gourma, but has continued to work in the northern regions Timbouctou, Gao and Kidal. There have been some security

problems in relation to the implementation of programmes in Kidal. The latest incidence took place in the spring of 2008 with more than 50 people killed. NCA projects currently focus on good governance, support to decentralisation, strengthening women groups, building wells and developing solar energy. NCA has furthermore been involved in the fight against gender based violence and female genital mutilation.

CARE has continued its operations in Mali after the end of the SSE programme. CARE Norway is currently running projects in the regions of Segou, Mopti and Timbouctou. Agricultural development has been an important component in many projects. In CARE's strategy there is now a particular focus on gender based development. CARE has ceased working as a project implementer, but is now working through partner institutions.

The Strømme Foundation mainly focuses its support on primary education and microfinance. In addition to these NGOs, the Norwegian missionary organisations are also running development projects. *Det Norske Misjonselskap* is running a project on rural development in Doentza in the region of Mopti and *Normisjon* is running development projects of small scale horticulture and access to water in the regions of Kayes and Koulikoro. These projects are supported through *Bistandsnemda*, the umbrella organisation for Norwegian missionary organisations.

When the SSE programme ended in 1996, the NGOs that operated under the SSE programme decided to form the Drylands Coordinating Group (DCG). National DCG groups were later formed in Mali, Sudan, Ethiopia and Eritrea. DCG's primary objective is to contribute to improved food security for vulnerable households and communities in the drylands of Africa. DCG does not implement development projects, but focuses on action-oriented research, policy studies, advocacy- and policy work, and capacity building. This contributes to strengthening the organisation's competence in dryland issues. Recently DCG launched a web-page on Best development techniques and approaches for agricultural improvement in the Sahel

(http://www.drylands-group.org/Thematic_Focus/Agriculture/Best_techniques/index.html=).

The Department of International Environment and Development Studies, Noragric at the Norwegian University of Life Sciences has been technical advisor to DCG since its creation in 1996. DCG has also been active in relation to the UN Convention to Combat Desertification (UNCCD). The DCG chairman in Mali has been part of the Malian delegation to meetings of the UNCCD. Norwegian members of the DCG have also been part of the Norwegian delegation to the meetings of the UNCCD.

Throughout the years Norwegian NGOs and research institutions have developed considerable knowledge on development issues in the Sahel and in Mali in particular.

5. How agriculture in Mali can adapt to climate change and increase productivity

Subsistence oriented agriculture in Mali is characterized by cultivation of food crops, use of fallow, limited use of organic input, no use of chemical fertilisers and traditional animal fattening for the Islamic holidays. Productivity is low and grain yields are in the range of 300 to 500 kg/ha. Crop failures are common and farmers often have to re-sow their crops. In years of complete crop failure the farmers have to sell animals or engage in off-farm income activities in order to survive. It is often believed that rainfall is the most limiting factor for plant production in the drylands of West Africa, but research has shown that this is not the case. Plant production is more limited due to the availability of the plant nutrients

phosphorous and nitrogen than by rainfall (Breman and De Wit 1982). It is only when rainfall is below 300 mm that it becomes the most limiting factor for crop growth.

A process for developing a more integrated and more stable agricultural production system has recently been described by Aune and Bationo (2008). Agricultural development and intensification is described as climbing a ladder (Fig. 6). The first step on this ladder is to make better use of agricultural technologies that are without any cost to the farmers. This includes technologies like better use of organic fertiliser, water harvesting and seed priming. Seed priming consists of soaking millet and sorghum seeds in water for eight hours prior to sowing. This has been shown to increase yields in Mali by more than 50%. Another approach for improving yield without any cost to farmers is to encourage them to protect trees that are most valuable to them. Very good results have been achieved with this approach in Niger (source Chris Reij). The next step on the ladder is to use very small amounts of mineral fertiliser (microfertilisation). This has been found to kick start plant growth and a combination of seed priming with micro-fertilisation has been found to give very good results in Mali. Millet yields have more than doubled and the method has been very profitable. Farmers can furthermore strengthen the livestock component of the farming system by increasing cowpea density which is a very important grain legume in the drylands of West Africa and use improved fodder schemes for the animals. More advanced farmers can furthermore initiate agroforestry systems based on different Acacia species that can provide animal fodder and windshed. It is unlikely that subsistence oriented farmers can move directly to the highest level on the ladder as each step represents the foundation for climbing to the next. The necessity for labour and institutional support increases as farmers climb the ladder. Such an intensification process must therefore be backed by political and financial support.

Agricultural intensification will always entail some risks. The major risks for dryland farmers are related to production, prices and institutional support. The major production risks are drought, pests and diseases. Price risks are related to the collapse of prices in good years. The institutional risks are related to land tenure, access to credit, and sustainability of local institutions. The health situation in the family is an additional risk factor that the farmers have to deal with. By combining indigenous methods for risk management with technological advances such as improved farming methods and meteorological services it is possible to develop farming systems that are productive and more robust. In order to minimise the institutional risks it is important to build farmers' organisations that are capable of dealing with these different forms of stress.

There are strong crop-livestock interactions in the dryland areas in Mali. Pastoralists have traditionally been invited to graze on cultivated land to their and the farmers' benefit. The cultivated land has benefitted from animal manure and the pastoralists have benefitted by getting access to fodder and water for their animals. The farmers are also livestock keepers and their animals also graze on the cultivated land. Farmers have also started to collect crop residue and use it as fodder in the dry season. An increase in crop production will be of great benefit to livestock production as the crop residues are used as animal fodder. If grain production is doubled through improved cultivation methods, this will also double the production of fodder since straw and grain production of cereals are closely related. If grain legumes are given more predominance in the crop production system, this will also contribute to improve the fodder quality because more protein rich material is provided. It is therefore possible to create positive synergies between crop and livestock production in the dryland areas. If the yield in crop production is increased, there will also be less pressure on

expanding the cultivated areas. Historically, an increase in grain production has been achieved by expanding cultivated areas, often at the expense of grazing areas.

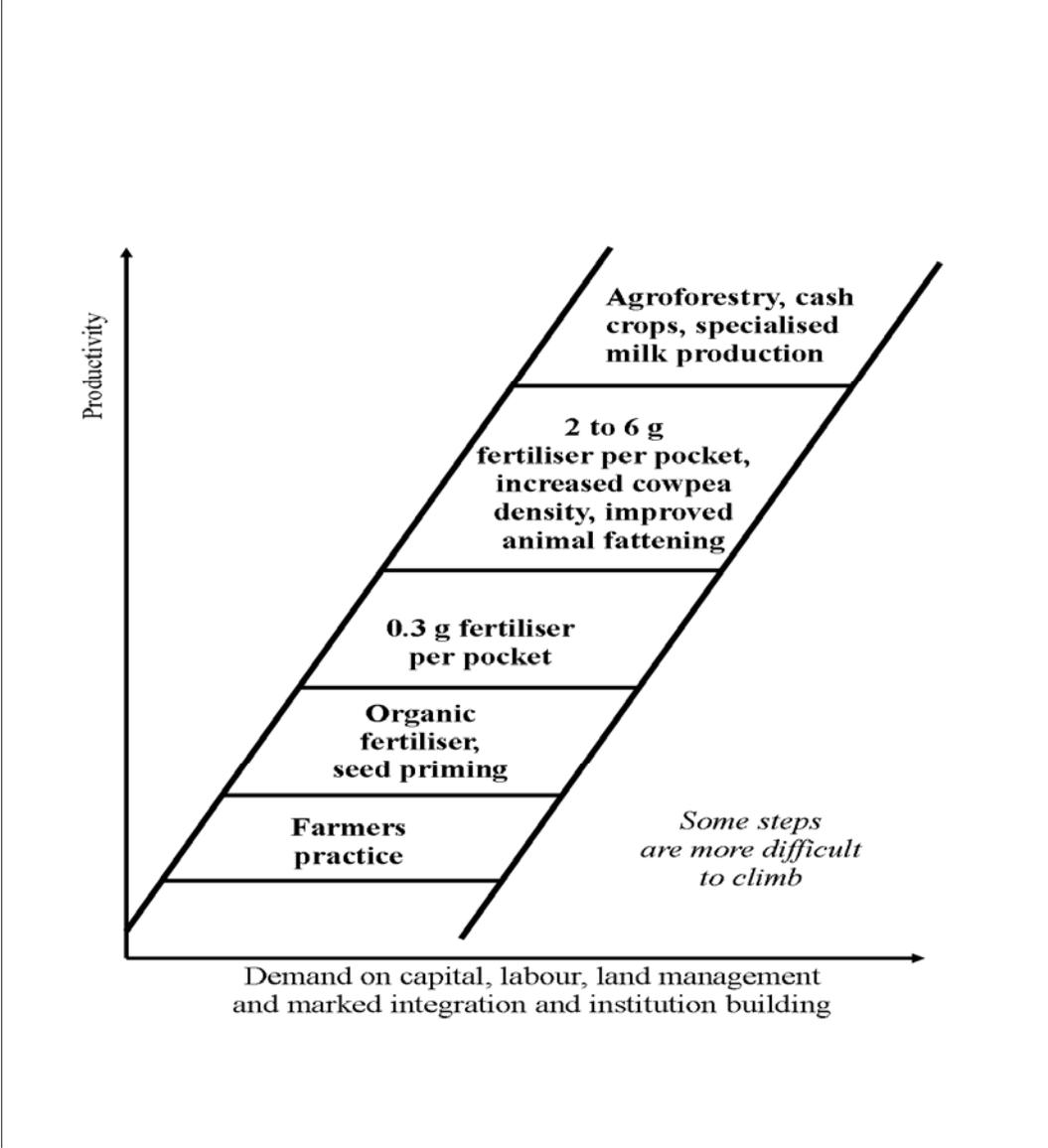


Figure 6. The ladder for agricultural intensification of drylands

There are many examples of clashes between pastoralists and farmers in the Sahel. These clashes are often related to access to grazing land in the dry period. Transforming wetland pastures into rice fields has been the origin of some of these conflicts. It is a challenge to reach pure pastoralists through development programmes. Previous experience shows mixed results with development programmes for pastoralists such as the West African Pilot Pastoral Programme. Initiatives to developing integrated farming systems that can strengthen both livestock and food production are more likely to be successful. Pastoralists are also becoming farmers. Parts of the extended family settle on farms whereas the other part of the family

practices traditional pastoralism. This diversifies the family's income and is insurance in times of drought.

Policies that can strengthen agricultural development in the dryland areas of Mali include improving access to input, institutional support and favourable price policies. Food prices in Mali have been relatively low for many years, but are now increasing due to the international rise in food prices. High food prices are beneficial to Malian farmers, but the government of Mali should keep an eye on prices in order to ensure that they remain reasonable both for consumers and producers. Donations from USAID have previously contributed to keeping food prices low in the Sahelian countries. There is furthermore a need to strengthen farmers' institutions. These institutions play a role in relation to management of land and to the supply of input like fertiliser and credit. Development of new agroforestry systems and the protection of regenerating trees are dependent on a common agreement among the land users. There is therefore a need to develop new institutions and policies that can ensure better management of pastures.

6. Adaptation to climate change in Mali - plans and on-going projects

Mali became signatory to the UNCCD in 1992 and the Kyoto protocol in 1999. A Designated Operation Entity that regulates the Clean Development Mechanism was established in 2003.

The responsibility to follow international environmental conventions in Mali lies with the Permanent Technical Secretariat of the Institutional Framework of Environmental Issues Management Secretariat (STP/CIGQE). STP/CIGQE is the focal point for the UNFCCC and UNCCD conventions and coordinates activities related to the conventions and reports to meetings of the conventions. The secretariat furthermore manages environmental information in Mali.

Mali has developed a preliminary nation action plan on climate change (NAPA). The final plan will be ready in 2008.. Important criteria for selection of new projects will be the impact on poverty and scarce resources and impact of economic growth in the country. Selection of new technologies will be based on cost-efficiency (Mali 2008). The plan includes the following components:

- Teaching farmers how to make use of agro-meteorological information
- Building and maintenance of wells
- Developing new cropping systems
- Digging of canals to irrigate more land and cleaning of canals that have been filled with sand
- Provoking rainfall
- Increasing the use of improved varieties that are adapted to local conditions
- Using new agricultural technologies (soil and water conservation)
- Diversifying agricultural production
- Strengthening early warning systems
- Establishing cereal banks
- Constructing new irrigation schemes based on water from the Niger and Boni rivers
- Strengthening fodder production (particularly of bourgou on the riverbeds)

- Improving access to credit for agricultural activities

Wood and charcoal are the main energy resources in Mali. Most Malians cook their food using these two sources of renewable energy. There is therefore high pressure on forest resources particularly near the larger cities. Mali has developed a strategy for domestic energy development. Important components of this strategy are:

- use of improved stoves
- promoting the use of gas for cooking
- improving the efficiency of producing charcoal
- establishing control of wood and charcoal markets
- improving management of forests, including replanting

Projects and programmes related to climate change are already being implemented, but it is difficult to get a complete overview of these projects. Projects and programmes in the northern regions include GTZ's programme on support to irrigation schemes along the Niger River in the Tombouctou region. DANIDA is assisting the government of Mali on water management issues including supporting a programme on developing drinking water in the regions of Sikasso and Mopti. Another DANIDA programme promotes private sector development including micro-finance.

The International Fund for Agricultural Development (IFAD) has a programme in the Kidal region supporting pastoral groups and it also funds a programme on capacity building of local organisations and institutions to express their collective needs and to realize and manage investments. The programme furthermore works on developing the agro-pastoral potential of the area and improving access to basic services.

Water in the Niger River is a key resource in Mali for irrigation, electricity production, fisheries and transport. It is projected that there will be less water in the river as a result of climate change. However, in 2008 the water level was a record high. A regional committee has been established for managing the Niger River water. The countries included in this committee are Benin, Burkina Faso, Côte d'Ivoire, Guinea, Cameroon, Mali, Niger, Nigeria and Chad. The committee's objective is to agree on how best to use the Niger River's water resources. The committee's headquarter is in Niamey, Niger.

7. Future Norwegian assistance to Mali related to adaptation to climate change in the agricultural sector

Future Norwegian development assistance to Mali related to adaptation to climate change should align with the Nation Action Plan on climate change and to other donor initiatives on climate change. There are many good intentions in Mali's action plan which generally is in line with previous environmental plans. Projects are already being implemented in many of the fields proposed for interventions. However, it must be assumed that many of the activities proposed are underfinanced. The government of Norway could therefore give support to some of the underfinanced areas in the plan.

There is a range of partners that could implement research and development projects in this field with the Ministry of Agriculture having overall responsibility.

The leading agricultural research institution in Mali is the *Institut d'Economie Rural* (IER) which falls under the Ministry of Agriculture. This is probably one of the best functioning

agricultural research institutions in West Africa. It generally has a very well qualified staff. IER also runs regional research centres spread across the agro-ecological zones in Mali. IER also has sound experience in the field of technology transfer and often works in partnership with other institutions such as the *Office du Niger* and CMDT.

There are many regional organisations operating in agricultural research and development in Mali. The international research institutions include The World Agroforestry Centre (ICRAF), the International Crop Research Institute for the Semi-arid Tropics (ICRISAT) and the West African Rice Centre (WARDA). AGRYMET of CILSS (*Comité Permanent Inter-Etats de lutte contre la Sécheresse*) in addition conducts research on meteorological issues and early warning systems in Mali. AGRYMET is located in Niger.

Development assistance to Mali should align with the programmes of the other major donors such as France, the Netherlands, USA and Germany. Multilateral institutions like the World Bank, IFAD and FAO are also active in Mali. Mali has created a harmonization action plan with the aim to better coordinate development assistance. The key document for development planning is the Poverty Reduction Strategy Paper from 2007 and many of the donors have aligned their assistance to this plan (World Bank). The donors have also established a technical support unit in order to better harmonise development assistance.

When engaging in future development assistance to Mali in the field of adaptation to climate change it is necessary to consider underlying socio-economic and demographic development trends as well as future projections for climate change. Food production in Mali must increase in the years to come in order to keep pace with population growth and increasing demand as a result of economic growth. Future climate is expected to be more unfavourable for agricultural development in Mali particularly because temperatures are expected to increase. Climate variability is also expected to increase. Mali should therefore prepare for more unfavourable agro-ecological conditions. Per capita food production has been declining for many years and in any case it makes sense to build an agriculture that is more productive and more robust to climate change. Good adaptation to climate change is generally good development (Brown and Crawford 2008).

Agricultural intensification in Mali has so far mainly taken place in the sub-humid areas and in relation to irrigated rice. It is a major challenge to initiate a process of intensification of agricultural production also in the dryland areas where the farming system is characterised by mixed crop-livestock production systems. Regions where such a research and development programme can be initiated are Mopti and Segou. These regions represent the transition zones between nomadic livestock production systems and permanent agricultural systems. These regions have been much less supported than the areas in the south where cotton is produced. Mopti is in addition the region in Mali with the most severe poverty.

Norway can take the initiative to develop a research and development programme with objective to make dryland agriculture in Mali more productive and robust to climate change. Such a programme will furthermore build more diversified livelihoods. This can contribute to reducing the impact of higher temperatures and strengthening crop livestock interaction. The plan may include the following components:

1. Reduce soil surface temperature. Higher temperature is a particular challenge in the Sahel since temperatures already limit crop growth in the region. The effects of high temperatures are particularly severe during crop establishment. One effective method to reduce soil surface

temperatures is to increase shade. Shade can be produced by developing different forms of agro-forestry. Shade does not only reduce soil surface temperature, but will also reduce water loss from soil and plants thereby making more water available for plant growth. One approach consists of protecting trees that regenerate naturally. Not all trees are desired from a farmers' point of view, but the farmers can select and protect the trees that are most valuable for them. This approach has been giving good results in Niger and thousands of hectares have regenerated naturally. The trees provide shade for the crops and fodder is produced through careful thinning of the branches. The leaves from the trees often have a very high fodder quality. This approach also provides fuel wood and building materials. This approach is in line with the Regreening the Sahel initiative proposed by Chris Reij. Another approach is to plant hedges of *Acacia tumida*. This drought resistant tree establishes quickly under Sahelian environments and provides windshed, shade and mulch after cutting the branches. The advantage with this tree is that the leaves are not edible by animals which makes the tree much easier to establish. It also produces seeds that can be used as chicken feed or for human consumption and does not compete with plants for water as it has a deep root system. The tree has been tested by the International Crop Research Institute (ICRISAT) in Niger and by the Drylands Coordination Group in Mali.

It is possible to use a combination of these methods in order reduce soil surface temperatures and improve crop establishment.

2. Reduce the time for plant establishment; kick-start the plants. Plant establishment in the Sahel is very critical and farmers often have to re-sow. Research conducted by the Drylands Coordination Group shows that it is possible to greatly improve crop establishment by combining the method of seed priming and micro-fertilisation. Seed priming consists of soaking the seeds in water for 8 hours prior to sowing and micro-fertilisation consists of applying small amount of mineral fertiliser at the time of sowing. Seed priming and micro-fertilisation can also be combined. Seed priming and micro-fertilisation kick-start plant establishment and root development is faster resulting in more drought resistant plants. This ensures a more uniform stand.

3. Establish water harvesting structures such as the zais (planting pits) and stonebunds/earthbunds. These structures retain water and reduce the risk for crop failure. They will also extend the growing season and increase yields. Use of fertiliser will also be more profitable when combined with water harvesting structures. Organic manure can also be applied to these planting pits thereby improving the soil's chemical and physical conditions enabling better crop establishment.

4. Provide farmers with crop varieties that are tolerant to drought and high temperatures. Farmers are often short of varieties that are adapted to local conditions. It is therefore important that farmers have access to appropriate varieties and seeds of good quality. Special emphasis should be given to providing seeds of dual purpose grain legumes that can produce grain as well as fodder for the animals.

5. Livestock development focusing on increased fodder production and better fodder schemes. Fodder production can easily be doubled as a result of the improved crop management methods described above. The fodder's quality can also be improved by harvesting earlier and using more legumes as fodder. ILRI has also developed an improved fodder ration that improves the protein content and reduces waste. Increased fodder production will make it possible for the farmer to store more fodder which can be used in crisis situations. An increase

in crop production will reduce the pressure on pastures since there will be less need for expanding the cultivated area. This will also benefit passing pastoralists.

6. Development of farmers' institutions in the area of land management, conflict resolution, input supply and management credit and saving schemes. Support to building of input supply network for seeds, fertiliser and other input.

7. Training of Malian decision makers and students at MSc and PhD level in the field of adaptation to climate change. The training of Malian decision makers can be organised through STP/CIGQE.

Partners in such a programme can include the *Institut d'Economie Rural*, STP/CIGQE, the Ministry of Environment (focal point in Mali on climate change), the Ministry of Agriculture, the Malian Farmers Association (*Chambre d'agriculture*) and local NGOs. The proposed programme can have a research and a development component. The research component can focus in particular on development of new farming systems that are more adapted to climate change whereas the development component can focus on training farmers, improving input supply and building farmers' institutions (see points above). The programme can be initiated by a pre-project phase to develop a full proposal and to identify possible partners. Such a programme will be rooted in the Malian institutions and will strengthen these institutions in the field of adaptation to climate change.

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