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Agricultural residues for energy production in Mali

DANIDA contract 1711

Feasibility of renewable energy resources in Mali

December 2012

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Manuel harvesting of rice at l'Office du Niger

Photo:

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List of acronyms

CNESOLER	Centre National de l’Energie Solaire et des Energies Renouvelables
CMDT	Compagnie Malienne pour le Développement des Textiles
DANIDA	Danish International Development Agency
DGG	Department of Geography and Geology
DNE	Direction Nationale de l’Energie (Nationale Directorate of Energy)
DTU	Technical University of Denmark
EDM	Energie du Mali
ENI-ABT	Ecole Nationale d’Ingénieurs-Abderhamabe Baba Touré
FAO	Food and Agriculture Organization
GTZ	Deutsche Gesellschaft für Technische Zusammenarbeit
IER	L’Institut d’Economie Rurale
IPCC	Intergovermental Panel on Climate Change
IPR	L’Institut Polytechnique Rural
MMEE	Ministère des Mines, de l’Energie et de l’Eau (Ministry of Mines, Energy and Water)
OHVN	Office de la Haute Vallée du Niger
ON	Office du Niger
NPP	Net Primary Productivity
SDDZON	Schéma Directeur de Développement pour la Zone de l'Office du Niger (Masterplan for development of Office du Niger)
SNDR	Stratégie Nationale de Développement de la Riziculture (National strategy for development of rice cultivation)
SOSUMAR	SOciete SUcriére de MARkala
UNEP	United Nations Environmental Programme
URC	UNEP Risø Centre
UTM	Universal Transverse Mercator

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1 Preface

The supply of affordable, reliable and environmentally friendly energy services is an important precondition for the economic development of Malian society. Currently demand for electricity is increasing by about 10% per annum, and demand for fuel for transport is increasing at an even higher level (BAD 2010). This presents enormous challenges to the Malian government and to national operators in reducing imports of fossil fuels, as well as to the national electricity utility, EDM (Energie du Mali), and to private investors in providing sufficient electricity at reasonable prices.

A large part of electricity production comes from large-scale hydropower produced on the Senegal and Niger rivers, but small- and large-scale diesel generators are still providing about 20% of total production. While interconnectors are being planned and built to meet some of the demand with electricity produced from natural gas in Ghana and Ivory Coast, there are still good political and economic reasons to tap into abundant national renewable energy resources, such as hydro-energy, solar energy, wind energy, biomass residues from agriculture, and energy crops producing liquid biofuel.

Since the 1980s, in cooperation with various development partners, Mali has conducted a number of development projects and programmes focusing on the increased use of renewable energy sources, while the Ministry for Mines, Energy and Water has developed a strategy for the development of renewable energy in Mali, which was adopted by the Ministerial Council (Conseil des Ministres) on 26 December 2006 (MMEE 2007). This strategy combines the aims of reducing poverty, validating national energy resources and ensuring the long-term security and environmental sustainability of the energy supply. Given the rapid increase in prices for imported fuels such as diesel and gasoline, it is increasingly worthwhile to assess the potential for giving renewable energy resources a central role in the future energy system: environmentally friendly renewable energy resources are abundant in Mali and are becoming increasingly competitive.

For the purpose of planning future investment in the renewable energy sector, the Malian energy authorities, Energie du Mali, private operators and international cooperation partners have expressed their needs for a more precise assessment of the size and variety of renewable energy resources in Mali. The Danish International Development Agency (DANIDA) has therefore provided the finance to map renewable energy resources under the heading of the ‘Feasibility of Renewable Energy Resources in Mali’, or ‘Faisabilité de Resources d'Energies Renouvelables au Mali’.

A first scoping phase of the project was conducted in 2007-2008. The project report, submitted in 2008 and entitled ‘Provisional mapping of Renewable Energy Resources in

Mali, or ‘Carte provisoire de ressources renouvelables du Mali’, was based entirely on satellite data and meteorological models.

The present project has taken the first study further by including ground measurements of wind and solar resources, and by including extensive field studies to assess the potential for using biomass waste for energy and to assess the socio-economic impacts of growing cassava for biofuel production. Not all renewable energy resources have been mapped, however. The most important exception is the stock of energy resources contained in Mali’s woody vegetation, which is not easily assessed from satellite data but is being assessed by other on-going projects.

The present project is covered in five main reports:

1) Analyses of the potential for sustainable, cassava-based bio-ethanol production in Mali
2) Agricultural residues for energy production in Mali
3) Pre-feasibility study for an electric power plant based on rice straw
4) Estimates of wind and solar resources in Mali
5) Screening of feasible applications of wind and solar energy in Mali, using the wind and solar maps for Mali

The project is being carried out by a group of university departments, research institutions and consultants led by the UNEP Risø Centre (URC) at the Technical University of Denmark (DTU) and conducted in cooperation with Direction Nationale de l’Energie (DNE) and Centre National de l’Energie Solaire et des Energies Renouvelables (CNESOLER) in Mali. The subcontracted institutions comprise Geographic Resource Analysis & Science A/S (GRAS), Department of Geography and Geology (DGG), University of Copenhagen, Ea Energy Analyses, 3E, Ecole Nationale d’Ingénieurs Abderhamabe Baba Touré (ENI-ABT) and Mali Folkecenter Nyetaa.

The drafting of this report and the research behind it has been led by Ivan Nygaard of URC, with input and support from the remaining authors.

2 Introduction

This report provides an assessment of the main agricultural residues available for electricity production. An initial screening made it clear that focus should be on two main agricultural cash-crops, rice and cotton, as these are the most important in terms of total amount, but also in terms of concentration of production, hence providing the best opportunity for use for electricity production.

The criteria for a crop to considered ‘interesting’ from a bio-energy perspective are firstly that there is a significant production of residues, e.g. straw, concentrated within a limited area. Secondly, the alternative uses of this resource, e.g. for fodder purposes, should be of considerably lower value, either because the pressure for using it for fodder is low or because the nutritional value of the agricultural residue in question is low. Thirdly, resources that are otherwise burnt are considered particularly interesting, since the potential economic loss associated with using the biomass for energy purposes, may be expected to be low or even negative.

This report provides a spatial description of the actual and the prospective production of crop residues from rice and cotton on a national basis, and a detailed study of the current use of rice straw from Office du Niger (ON), a large irrigation scheme producing rice. Office du Niger has the highest concentration of crop residues for electricity production in Mali and is located close to a newly established high voltage transmission line, which will allow for the transport of excess energy from a potential power plant. A pre-feasibility study assessing the technical, economic feasibility of a straw fired power plant is documented in a separate report, “Pre-feasibility study for an electric power plant based on rice straw”.

3 Study approach and methodology

3.1 Conceptual framework

The potential of biomass can be estimated at different levels. These levels are named and defined slightly different in the literature (e.g. Rosillo-Calle, de Groot *et al.* 2007, Smeets, Faaij *et al.* 2007, Rettenmaier, Reinhardt 2008). A widely used definition is provided in Table 3.1, which defines theoretical, technical, environmental, economic and sustainable potential.

Table 3.1. Definitions of resource potentials (Rettenmaier, Reinhardt 2008)

Biomass potential	Explanation
Theoretical potential	The maximum amount of terrestrial biomass which can be considered theoretically available for bioenergy production within fundamental bio-physical limits.
Technical potential	The fraction of the theoretical potential which is available under the regarded techno-structural framework conditions and with the current technological possibilities (such as harvesting techniques, infrastructure and accessibility, processing techniques), also taking into account spatial confinements due to other land uses (food, feed and fibre production) as well as ecological (e.g. Nature reserves) and other non-technical constraints.
Environmental potential	The fraction of the theoretical potential which meets certain environmental criteria, related to biodiversity, soil and water protection.
Economic potential	The share of the technical potential which meets criteria of economic profitability within the given framework conditions.
Implementation potential	The fraction of the economic potential that can be implemented within a certain time frame and under concrete socio-political framework conditions, including economic, institutional and social constraints and policy incentives.
Sustainable potential	The fraction of the technical bio mass potential which can be developed in a way which does not oppose the general principles of sustainable development, i.e. the fraction that can be tapped in an economically viable manner without causing social or ecological damage. Next to reducing global warming (greenhouse effect) and saving fossil energy, these goals include nature, soil and water conservation, for example. These sustainability goals can both decrease (e.g. through more area dedicated to conservation and therefore withdrawn from bioenergy use) or increase the biomass potential, e.g. if biomass from landscape conservation activities is included.

The theoretical potential includes all biomass that can be collected and used. In the scoping study the theoretical potential in terms of the 'net primary productivity' (NPP) was estimated based on satellite images.

This study will estimate the technical potential for rice straw and cotton stalks at national level and the sustainable potential of rice straw in the Office du Niger and the sustainable potential of cotton stalks in the zone of Koutiala in the Sikasso region.

3.2 Methodology

Agricultural statistics are normally only concerned about the crop yield, in this case the amount of paddy rice (un-hulled) and the cotton (lint).

The annual **technical potential** of rice straw is calculated by multiplying a straw-to-grain ratio (residue-to-product ratio) to the statistical information of annual production of paddy rice. Likewise, the annual **technical potential** of cotton stalks is calculated by multiplying a residue-to-product ratio to the statistical information of cotton production. Statistical info on production of rice and cotton is provided in chapter 5 and 10. The residue-to-product ratios for rice and cotton reflecting the **technical potential** are estimated based on the discussion below.

3.2.1 Straw-to-grain ratio (rice)

Straw-to-grain ratios are dependent on the soil quality, the fertilizer level, the variety of rice and not least the cutting height when harvesting.

Fertilizer level

An example of how the straw-to-grain ratio is influenced by fertilization rate in trials in California is shown in Figure 3.1.

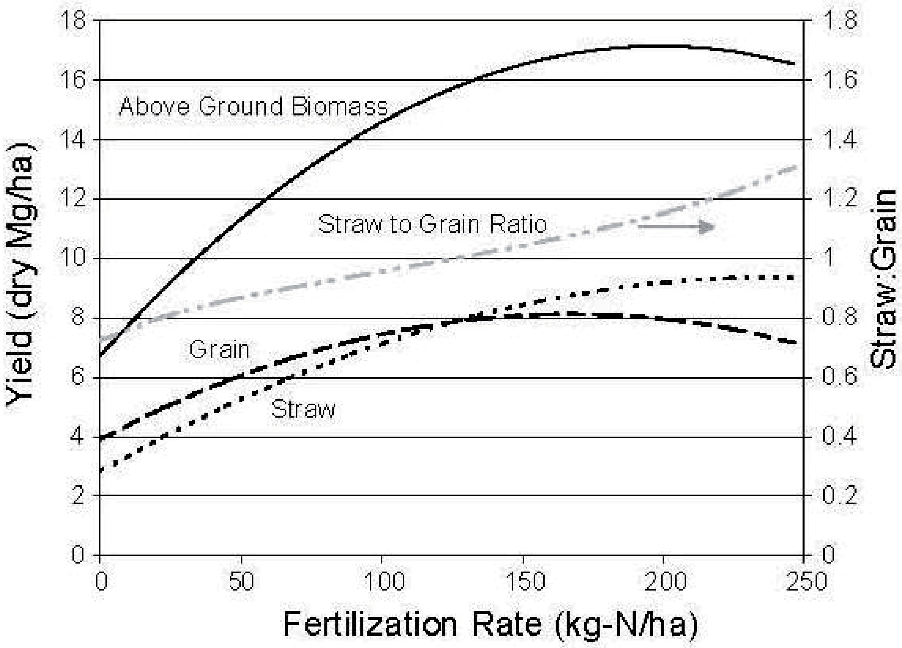

Figure 3.1. Straw-to-grain ratio contingent on fertilization rate (Summers, Jenkins et al. 2003)

Cutting height

The straw-to-grain ratio depends strongly on cutting height. The cutting height seems to be relatively high in the area for the time being due to a wish to reduce the amount of straw to be threshed and to leave stubble in the field for grazing of cattle and for soil improvement. Cutting height and the relationship between harvested straw and grain are illustrated in the pictures from fieldwork shown in Figure 3.2.

Figure 3. Illustration of cutting height of rice straw in the zone of Niono, Office du Niger (Rasmus Borgstrøm, 2010)

Variety

According to the questionnaires, in Niono, N'debougou and Molodo 68 % of harvested rice was the GAMBIAKA variety. The varieties Adiny 11 and Wassa covered 24 %, and the last 6 % were other varieties. Results are shown in Table 3.2. According to Mr Yacouba Doumbia from Institute Economie Rurale (IER) in Mali, the straw-to-grain ratio in Mali is between 0.6 and 0.9 for the varieties, Adiny 11, Wassa and Kogoni91-1, and 0.5-0.66 for the varieties Gambiaka and Kokum. Using the mean of the interval provided by Mr Doumbia, the straw-to-grain ratio will be 0.58 for Gambiaka and 0.75 for Adini-11 and Wassa, which indicates an average straw-to-grain ratio of 0.63 for the three zones. Results are shown in Table 3.3

Table 3.2. Share of rice production per rice variety in 2009 (questionnaires) and estimated straw-to-grain ratio (personal communication Yacoba Doumbia, IER)

Variety	Share of production	Straw-to-grain ratio
GAMBIAKA	68%	0.58
ADINY 11	12%	0.75
WASSA	12%	0.75
BG	3%	0.75
SAMBALA MALO	2%	0.75
IER 32000	1%	0.75
NERICA	0%	0.75
Average	100 %	0.63

Discussion

In the scientific literature the straw-to-grain ratios are generally much higher but vary considerably. For estimation of rice straw in India, Thailand and the Philippines, Gadde, Menke *et al.* (2009) used a straw-to-grain ratio of 0.75. For estimation of rice straw in Japan, Matsumura, Minowa *et al.* (2005) used a residue-to-product ratio of 1.2 based on dry weight. Both rice straw and rice husks are included in this figure, at a ratio or 8 (rice straw) to 2 (rice husk). Based on this the straw-to-grain ratio is 0.96, and the rice-husk-to-straw ratio is 0.24. For estimation of rice straw resources in Thailand, Matsumura, Minowa *et al.* (2008) used a straw-to-grain ratio of 1.19. A factsheet from FAO on rice production claims a straw-to-grain ratio of 1.1 for most currently planted rice varieties (FAO 2007).

The values from the literature are considerably higher than suggested by Mr Doumbia, but the fertilizer levels are presumably lower in Mali than in Thailand, Indonesia and Japan, and not least the cutting height is higher. Both factors reduce the straw-to-grain ratio. However, taking into account that the straw-to-grain value may increase when a market for straw to energy is established, we retain a value of 0.75 for calculating the **technical potential** of rice straw for energy use.

Table 3.3. Comparison of straw-to-grain ratios from various sources

Straw-to-grain ratio	Variety	Country	Source
0.416 to 3.96	Mixed	Global	(Koopmans & Koppejan 1998)
0.75	Mixed	India, Thailand, Philippines	(Gadde, Menke et al. 2009)
0.96	Mixed	Japan	(Matsumura, Minowa *et al.* 2005
1.11	Mixed	Global	(FAO 2007)
1.19	Mixed	Thailand	(Suramaythangkoor and Gheewala 2008)
0.6-0.9	Adiny 11, Wassa	Office du Niger	DOUMBIA Yacouba, IER
0.5-0.66	Gambiaka Kokum	Office du Niger	DOUMBIA Yacouba, IER
0.63	Average	Office du Niger	DOUMBIA Yacouba, IER

3.2.2 Residue-to-product ratio for cotton

As for rice straw, residue to product ratios for cotton varies significantly depending on soils, fertilizer level and cotton variety. It was not possible to find any estimates for the residue-to-product ratio for cotton in Mali, so this study has to rely on estimates from the scientific literature. Comparison of residue-to-product ratios for cotton from various sources is shown in Table 3.4.

Table 3.4. Comparison of residue-to-product ratio for cotton from various sources

Residue to product ratio	Variety	Country	Source
1.76-3.74		Asia	(Koopmans & Koppejan 1998)
2.9		USA	Coates 2000
1.77-5		Turkey	Hepbasli, Utlu *et al.* 2007
1		Sudan	Abdallah 1991
3.0		India	Tripathi, Iyer *et al.* 1998
2.1		Zimbabwe	Jingura and Matengaifa 2008

Based on the sources in Table 3.4, this study will use a residue-to-product ratio of 2.0 for calculating the **technical potential** for cotton stalks to energy.

4 Field study methodology

Field studies were conducted in order to estimate the current use of rice straw and cotton stalks. The objective hereby is to move from the technical potential to a sustainable potential, - as defined in chapter 3.

4.1 Planning and testing of questionnaires.

In order to get a common understanding of the field work methodology and the achievable outcome, a common field mission including the Danish and Malian partners was conducted in December 2009.

The mission had several objectives:

- taking a final decision of the scope of the study
- informing the authorities, Office du Niger and CMDT about the project
- collecting statistical data and GIS data on the current production
- testing and improving two draft questionnaires, one for the rice area and one for the cotton area

The composition of the team and the initial findings are available in Mission report 1.

4.2 Scope of study

In the project document it was envisaged that a scoping mission should make a final decision on whether the feasibility study for a power plant should focus on cotton stalks or rice straw. During the field mission in December 2009, it was decided that the feasibility study should comprise a power plant using rice straw and that this power plant should be located close to Niono, which is situated in the middle of the large irrigation scheme, Office du Niger. This decision was based on the fact that the highest concentration of agricultural residues was available at Office du Niger, and the fact that a new power line was going to be established from Niono to Segou, hence providing opportunity for selling the electricity to the grid. Also a reluctant interest in the project at the meeting with CMDT supported this decision (Mission report 1)

This choice was reflected in the design of the field study, in which the distribution of interviews was 300 for rice and 100 for cotton. For the rice straw about 160 interviews were carried out in the three zones in Office du Niger, Niono, N'debougou and Molodo, and 120 interviews in the zones of Macina and Mopti Nord. The distribution of interview in the area of Office du Niger is shown on the map in Figure 4.1.

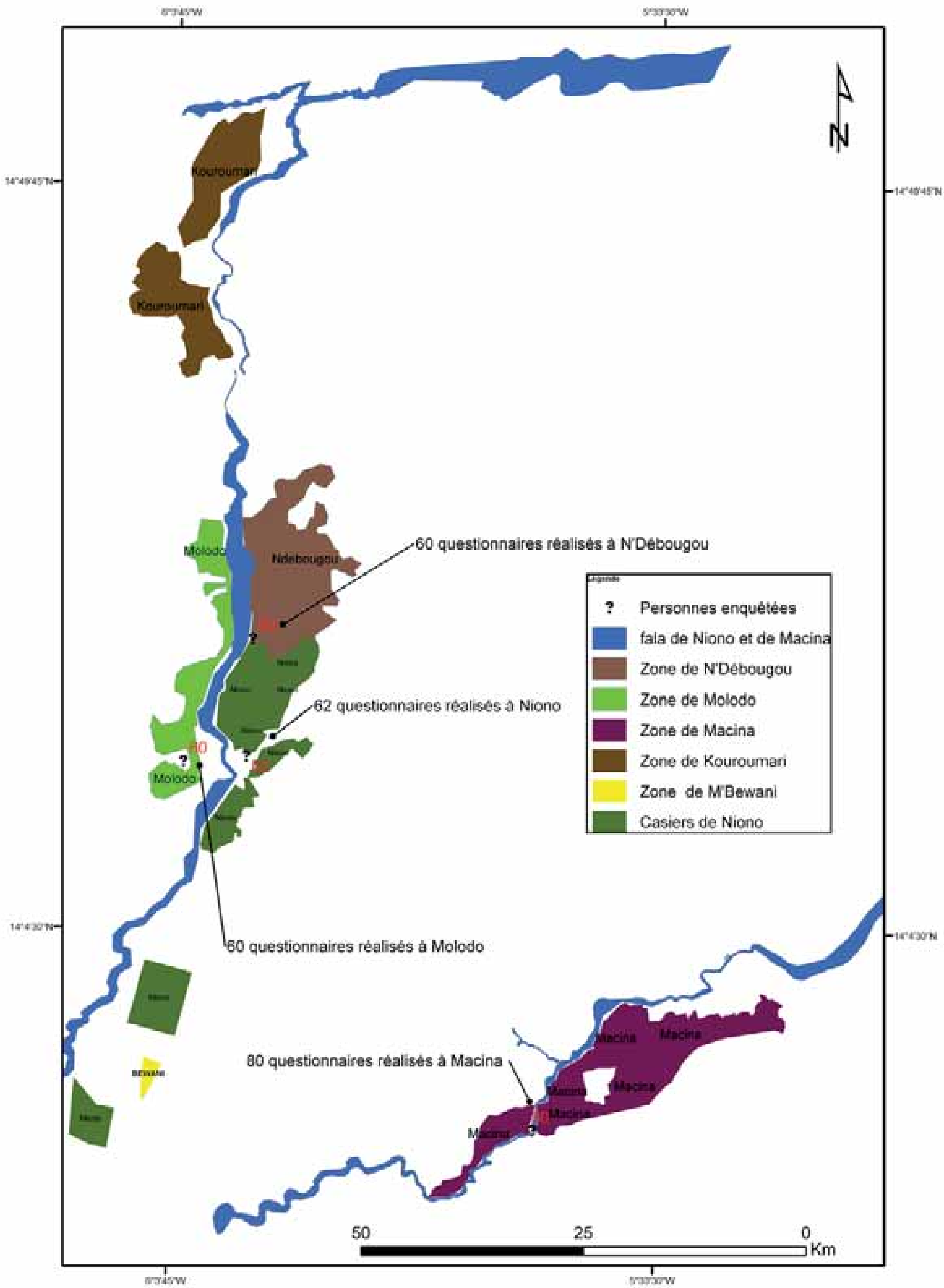

Figure 4.1. Office du Niger: Zones of research and distribution of interviews

All interviews concerning cotton stalks were carried out in the Koutiala area in the Sikasso region in the zones (CMDT), Koutiala, M'Pessoba, Konséquéla, Kouniana, Karangan, Molobala and Yorosso. Distribution of interviews in different zones of rice and cotton production is shown in Table 4.1.

Table 4.1. Distribution of interviews in different zones for rice straw and cotton stalks

Rice zones		Cotton zones	
Name of zone	Interviews	Name of CMDT sector	Interviews
Niono	62	Koutiala	20
N'Débougou	61	M'Pessoba	10
Molodo	60	Konséguéla	10
Macina	80	Zébala	10
Mopti Nord	42	Karangana	25
		Molobala	15
		Yorosso	10
Total rice	305	Total cotton	100

.

4.3 Conducting the interviews

According to the original plan the interviews should be conducted by a small group of 3-5 interviewers local to the interview area, who should be contracted for this specific job on a day to day basis. As the questionnaire comprises a large number of various socio-economic data, it was planned that the interviewers should receive one day of training by Oumar Fatogoma Traoré from Mali Folkecenter, to allow for a thorough understanding of the meaning and intention of the questions. It was envisaged to conduct the interviews based on a randomised sampling of the farmers in the area, and to document the geographical spread by using a GPS for the interviews.

Due to a number of constraints during the mission, each of the zones around Niono (Niono, N'debougou, Molodo) was covered by one interviewer each, while the zones Macina and Mopti-Nord were divided between two interviewers.

Table 4.2. Interviewers, positions and zones of research

Zones of research	Name	Position	Institution	Inter-view
Niono	Ms Fatalmoudou Maiga	Enquetrice[1]	ON-Niono	62
N'Debougou	Mr Yacouba Kouriba	Enqueteur	ON-Niono	61
Molodo	Mr Abdoulaye Diakite	Enqueteur	ON-Niono	60
Macina	Mr Adama Coulibaly	Intern	ON-Kolongotomo	41
Macina	Mr Sékou Sallah Diarra	Intern	ON-Kolongotomo	39
Mopti-Nord	Mr Filifing Dembélé	Researcher	IPR/MFC	18
Mopti-Nord	Mr Oumar F. Traore	Consultant	MFC	22
Mopti-Nord	Mr Alassane Maiga	Chef de *casiers*	Office Riz Mopti	2

The three interviewers for Niono, N'Debougou and Molodo were proposed by the responsible for promotion of farmers' organisations at Office du Niger. The three interviewers were trained for two hours, during which they had the opportunity to pose questions. Afterwards the interviewers took notes from a test interview conducted in Niono, whereupon the questionnaires were compared and discussed. Based on information on last year's production, the interviewees were selected using scales of production as the main stratification criteria and a geographical spread as second criteria.

1 Enqueteur is a person who assists in collecting field data

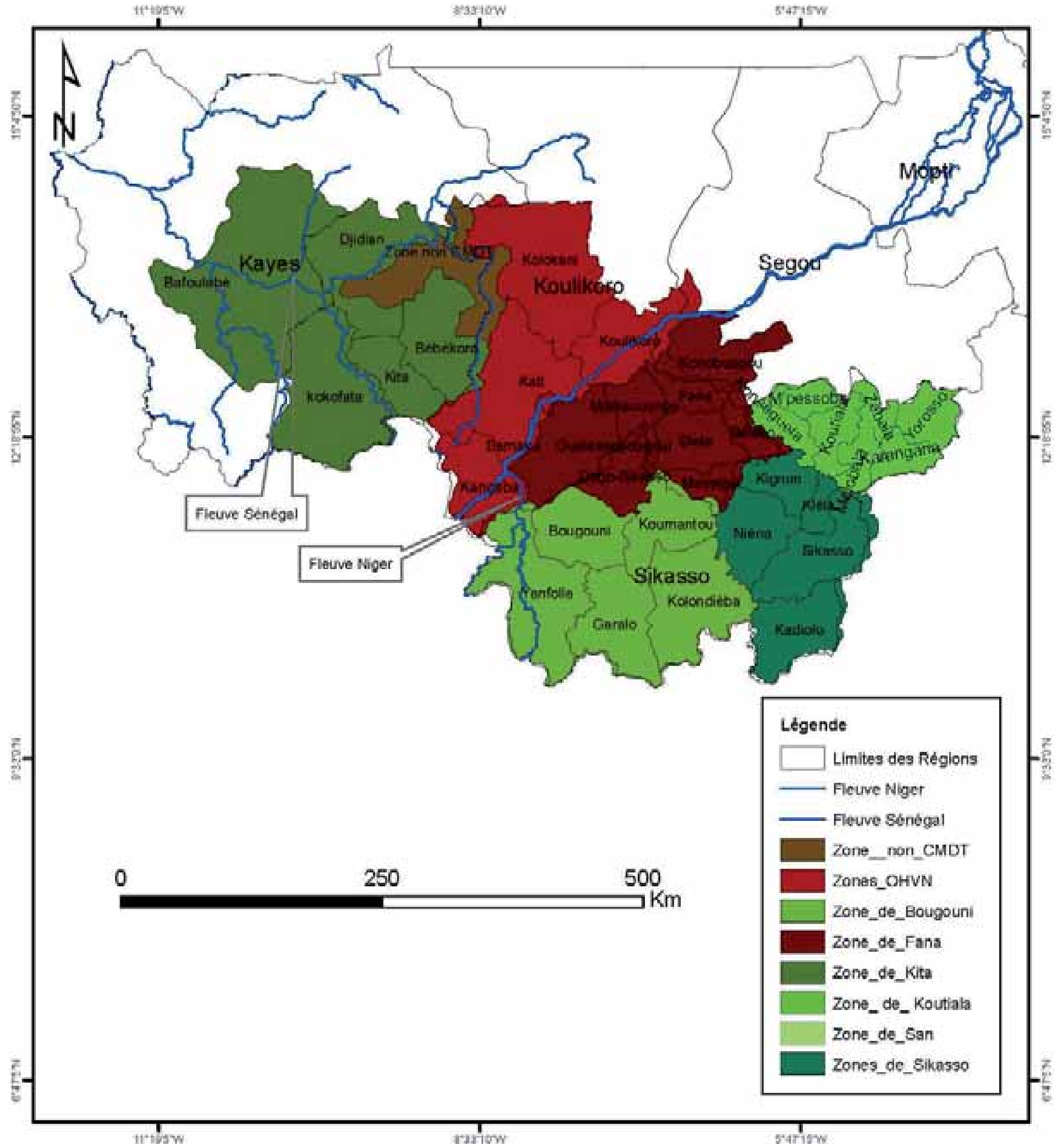

Figure 4.2. CMDT zones. Interviews were carried out in the CMDT zone in Koutiala. The CMDT zones are different from Malian administrative borders.

In Kolongotomo (Macina), two interviewers were proposed by the leading agent at Office du Niger (*Chef Division Appui au Monde Rural*). The interviewers were trained in filling out the questionnaires, but in this case no test interviews were conducted. Based on a report on last year's production the interviewees were selected using scales of production as the main stratification criteria and the geographical spread as second criteria.

In Mopti-Nord the interviews were conducted by Filifing Dembélé and Oumar F. Traoré from MFC, accompanied with two *'chefs de casiers'*. Based on the knowledge from the *chef de casiers* the interviewees were selected using scales of production as the main stratification criteria and the geographical spread as second criteria.

In Koutiala the interviews were conducted by local interviewers employed by the CMDT. The head of the Training Unit in CMDT was introduced to the questionnaires by Oumar Fatogoma Traoré, whereupon he trained the interviewers at a later stage. The CMDT zones in question are shown in Figure 4.2 and interviewers and the geographical spread of the interviews are shown in Table 4.3. Detailed information on the geographical spread of the interviews is shown in Annex C.

Table 4.3. Interviewers and CMDT sectors selected for research in the zone of Koutiala

	CMDT sectors							
Interviewers	Karan-gana	Kon-séguéla	Kou-tiala	Molo-bala	M'Pes-soba	Yoros-so	Zébala	Total
Amadou Maïga		10						10
Camara Araba Bagayogo					5			5
Falaye D. Sissoko				3				3
Ibrahim Togora				9				9
Issiaka N. Traore			5					5
Kady Coulibaly			5					5
Koniba Daou				3				3
Moussa B. Diarra					5			5
Molobaly Malle			5					5
Modibo Maiga			4					4
Ousmane T. Goïta							10	10
Sidi Mariko	25							25
Sékouba Traoré			1			10		11
Total	25	10	20	15	10	10	10	100

5 Technical potential of rice straw resources for energy at national level

This chapter assesses the **technical potential** of rice straw for energy production at national level. The technical potential is defined as the actual and prospective production of straw from rice cultivation in Mali. The technical potential includes a considerable amount of straw which cannot be exploited due to low density and a large amount which is currently used for other purposes, such as cattle feed.

This chapter is introduced by a statistical overview of the rice production in Mali and a review of existing plans for increased production. Hereupon, the technical potential of rice straw for energy production is estimated based on the uniform straw-to-grain ratio, which was discussed and defined in section 3.2.1

The **sustainable potential** of rice straw for energy production in Office du Niger is described in chapter 7.

5.1 Production of rice in Mali

Production systems for rice can be characterized according to their access to water, such as: i) irrigated rice, ii) rain-fed rice, iii) controlled flooding and iv) seasonally flooded areas (*bas fonds*).

In Mali, the majority of irrigated rice is cultivated in Office du Niger, but there are smaller irrigated areas around Segou, (Office du Segou), around Mopti, (Office du Mopti), San and smaller village based schemes on the river banks of the Niger and the Senegal River. While the cultivated area of irrigated rice in 2008/09 was about 125 000 ha, there is an untapped potential to increase the irrigated area up to 900 000 ha. Yields of irrigated rice vary between about 6 to 10 tonnes/ha (MA 2009).

Rain-fed rice was until recently practised at smaller areas in the south where rainfall is above 800 mm year. Yields are generally low, about 800 kg/ha. Recent introduction of new rice varieties has entailed higher yields up to 3-3.5 ton/ha, and rain-fed rice is increasing in Sikasso, Kayes and Koulikoro (MA 2009).

Rice under controlled flooding is practised at areas close to the Niger River in Segou and Mopti. While the cultivated areas were in 2008/09 about 74 000 ha, the yield of 0.8-2.5 ton/ha is relatively low compared to the irrigated areas (MA 2009).

Rice in seasonal flooded areas (*bas fonds*) constituted in 2008 about 14 000 ha mainly cultivated by women in the regions of Segou, Sikasso and Kayes. The yields of 0.8-2 ton/ha is relatively low compared to irrigated areas (MA 2009).

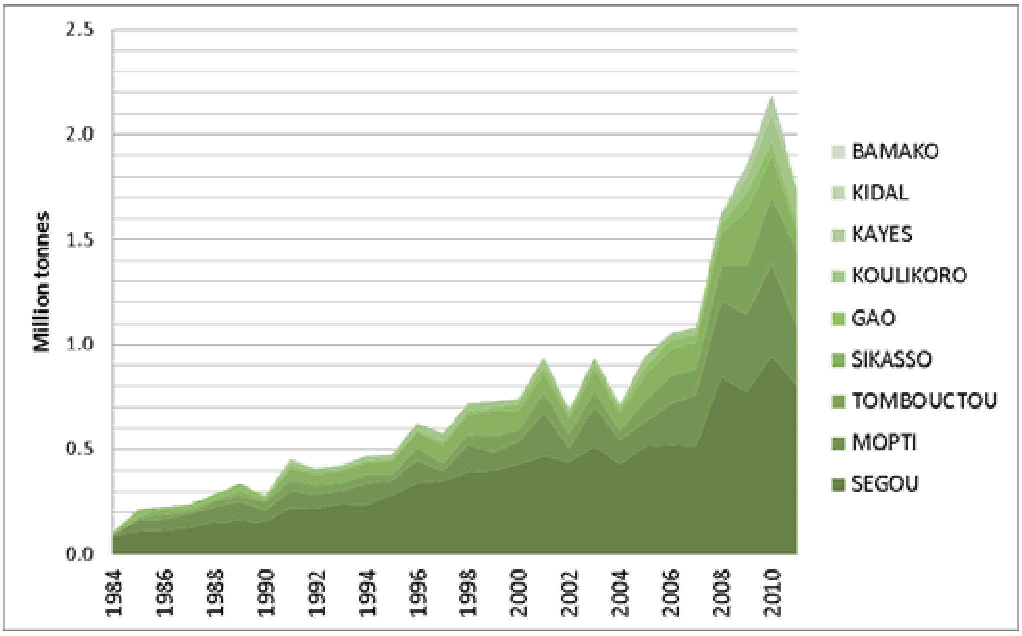

Figure 5.1. Production of rice (paddy) per region in the period 1984-2011 (source: FAO statistics 2012, www.countrystat.org)

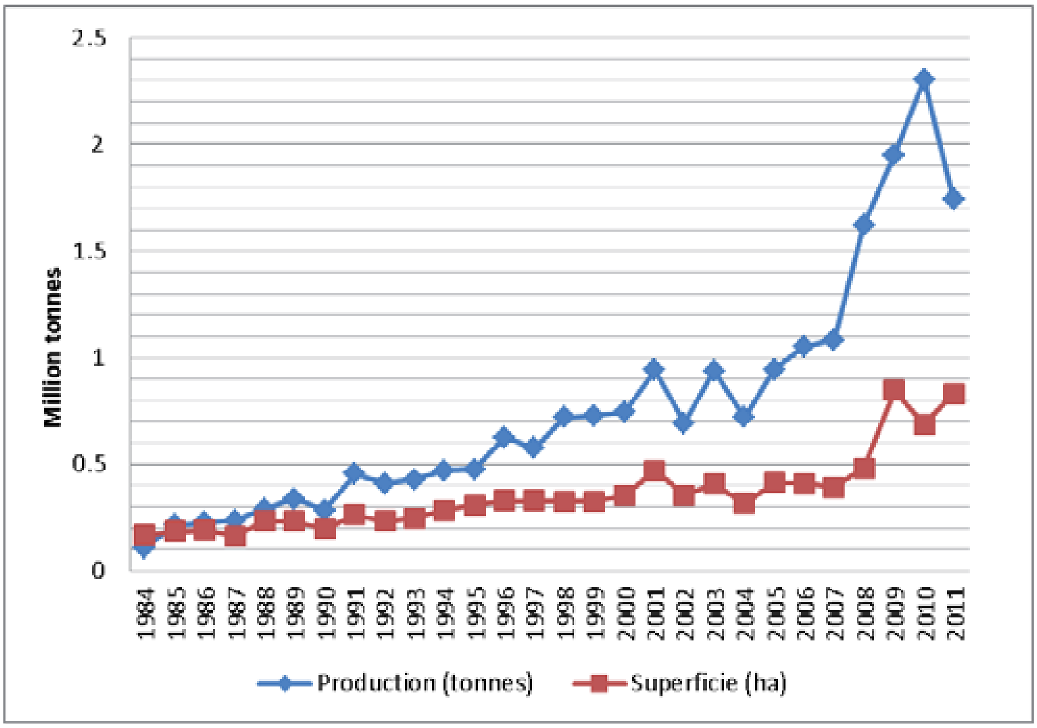

Figure 5.2. Rice production (paddy) and cultivated areas from 1984 to 2011 (Source: FAO statistics 2012, www.countrystat.org)

In 2006 the total production of rice was 1.05 million tonnes, of which 46 % was produced in Office du Niger, 3 % in Office du Segou and 1.5 % in Office du Mopti. As illustrated in

Figure 5.1, rice production has increased significantly during the last 20 years, from about 110 000 tonnes in 1985 to more than two million tonnes in 2010.

This is mainly due to increased production in the irrigated areas in Office du Niger, where the cultivated area has more than doubled in the period, and where the average yield increased from 1.6 tonnes/ha in 1982 to around 6 tonnes/ha in 2007 (Aw and Diemer 2005; 39)

The production from Office du Niger, Office de Secou and Office du Mopti is collected in Table 5.1 below. More details of production of rice in Office de Secou and Office du Mopti are presented in annex B. Detailed information on production of rice in Office du Niger is presented in chapter 6.

Table 5.1. Annual production of Rice in the three main rice areas in Mali (tonnes/year)

Campaign	Office du Mopti	Office du Segou	Office du Niger	Total
2006/2007	15 449	32 544	430 125	478 118
2007/2008	21 585	30 157	446 122	497 864
2008/2009	40 063	60 688	513 005	613 756

Source: Annual reports from the three entities

5.1.1 Future plans for the national rice production systems

The Malian Government launched its national strategy for rice cultivation in 2009 (MA 2009). According to the plan only about 20 % of the potential area suitable for rice production is currently exploited. As illustrated in Table 5.2, the unexploited potentials are available in all regions and ranges from 88 % in Tombouctou to 70% in Gao.

Table 5.2. Existing and potential areas for cultivation of rice in Mali according to the national strategy (MA 2009)

Regions	Potential (ha)	Cultivated (ha)	Cultivated (%)
Kayes	90 000	12 963	14
Koulikoro	110 000	22 439	20
Sikasso	300 000	47 517	16
Ségou	500 000	117 371	23
Mopti	510 000	150 814	19
Tombouctou	280 000	33 997	12
Gao	110 000	33 212	30
Total	2 200 000	418 313	19

The national strategy for cultivation of rice in Mali suggests more than doubling rice production from 1.6 million tonnes to 4 million tonnes in a ten year period from 2008 to 2018. Historical data for rice production and the estimated increase until 2018 is shown in Figure 5.3 below.

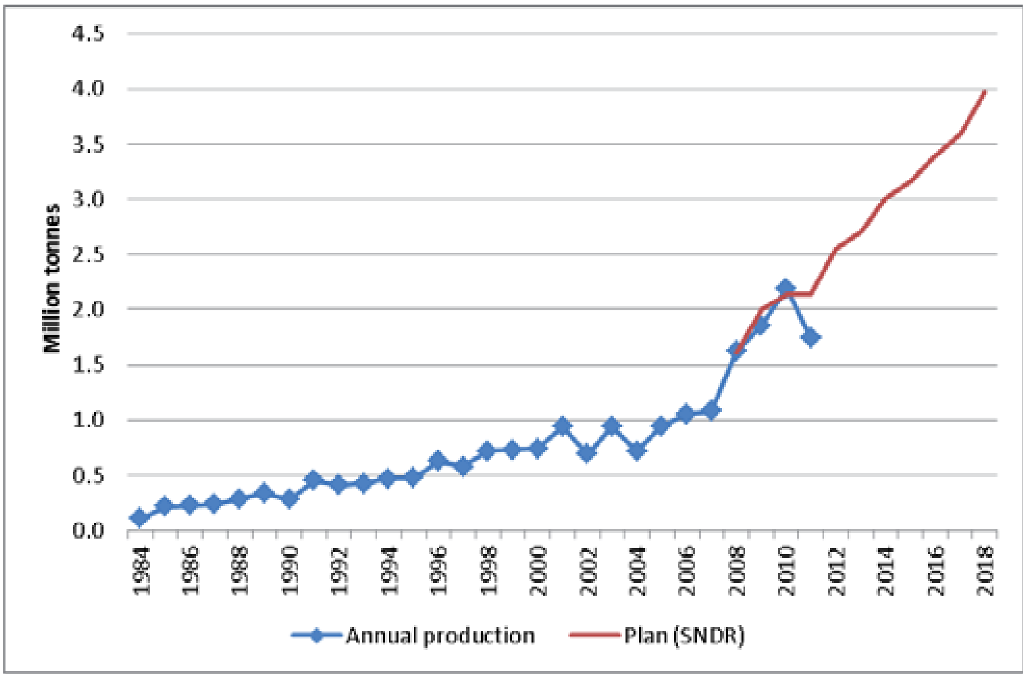

Figure 5.3. Annual production of rice (paddy) from 1984 to 2011 and planned production according to the National Strategic Plan for Rice (FAO statistics; MA 2009)

This expected increase in production is based on an increase in the cultivated area from 626,573 ha in 2008 to 1,087,254 ha in 2018, and an increase in average yield from 2.6 ton/ha to 3.6 ton/ha. The increase is mainly due to an increase in irrigated land of about 10,000 ha/year and an expected change to a drought resistant variety, NERICA of rain fed rice (MA 2009). Key figures from the plan are shown in Figure 5.4. Details on the planned expansion of Office du Niger are provided in paragraph 6.3 below.

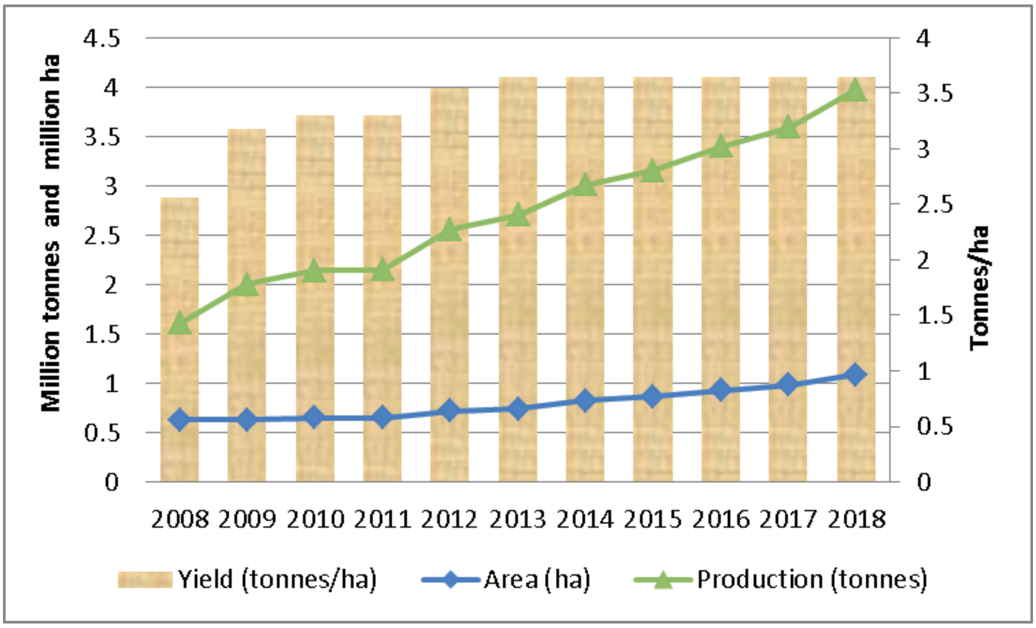

Figure 5.4. Key figures from national plan for rice production (MA 2009)

5.2 Technical potential of rice straw for energy in Mali

The technical potential of rice straw per year for energy in Mali is estimated based on the production of rice paddy shown in section 5.1 and the estimated average straw-to-grain ratio of 0.75, already described in section 3.2.1.

Figure 5.5 shows the technical potential of rice straw from 1984 to 2011. The estimated technical potential from 2011-2018 is based on the National Strategic Plan for Rice (MA 2009). The technical potential in 2011 is around 1.5 million tonnes in 2011, and is expected to increase to about 3.0 million tonnes in 2018 according to the forecast in the National Strategic Plan.

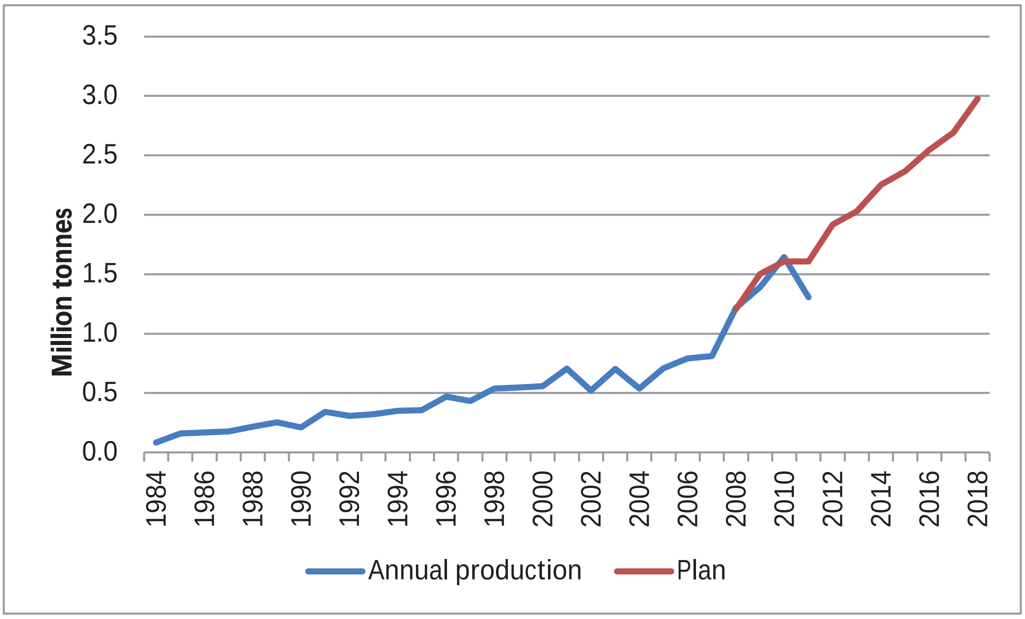

Figure 5.5. Technical potential of rice straw for energy production according to the National Strategic Plan for Rice (Million tonnes/year)

The major part of this straw is already used for cattle feed, incorporated into the soil for fertilizer or used for other purposes. The sustainable potential or rice straw may be less than 20 % of the technical potential depending on the density of straw and the pressure from cattle in the area. The result of the empirical study of the sustainable potential of rice straw for energy in Office du Niger is described in chapter 7.

The technical potential of straw per region is shown in Figure 5.6 and Figure 5.7. For more detailed information is needed on straw potential per region, the reader may consult Annexe B for production statistics for rice (paddy) and multiply with the average straw-to-grain ratio of 0.75.

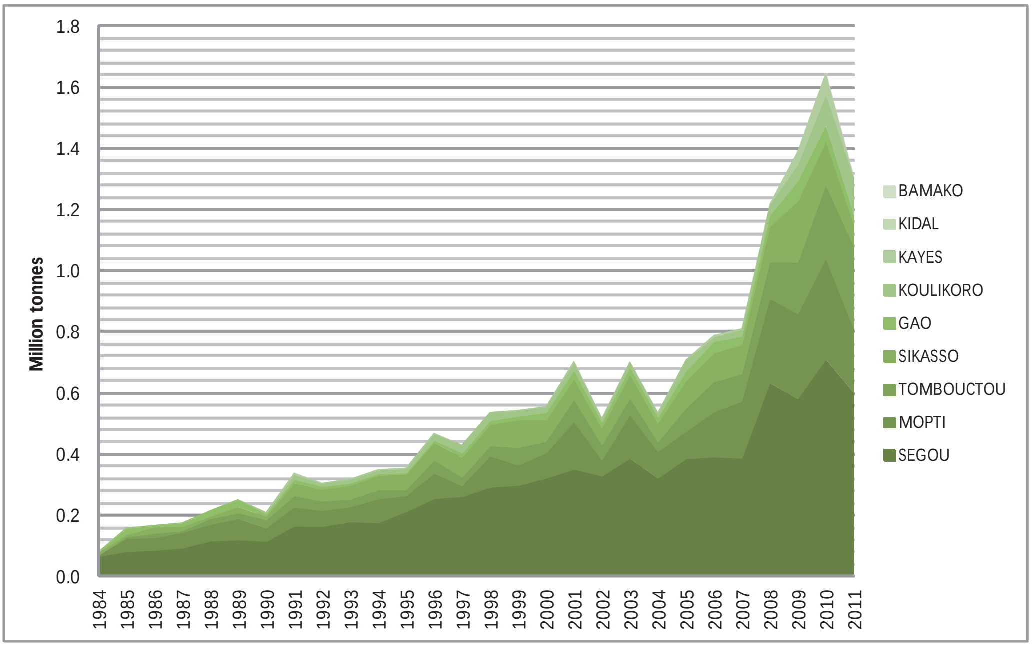

Figure 5.6. Technical potential of rice straw for energy per region in the period 1984-2011

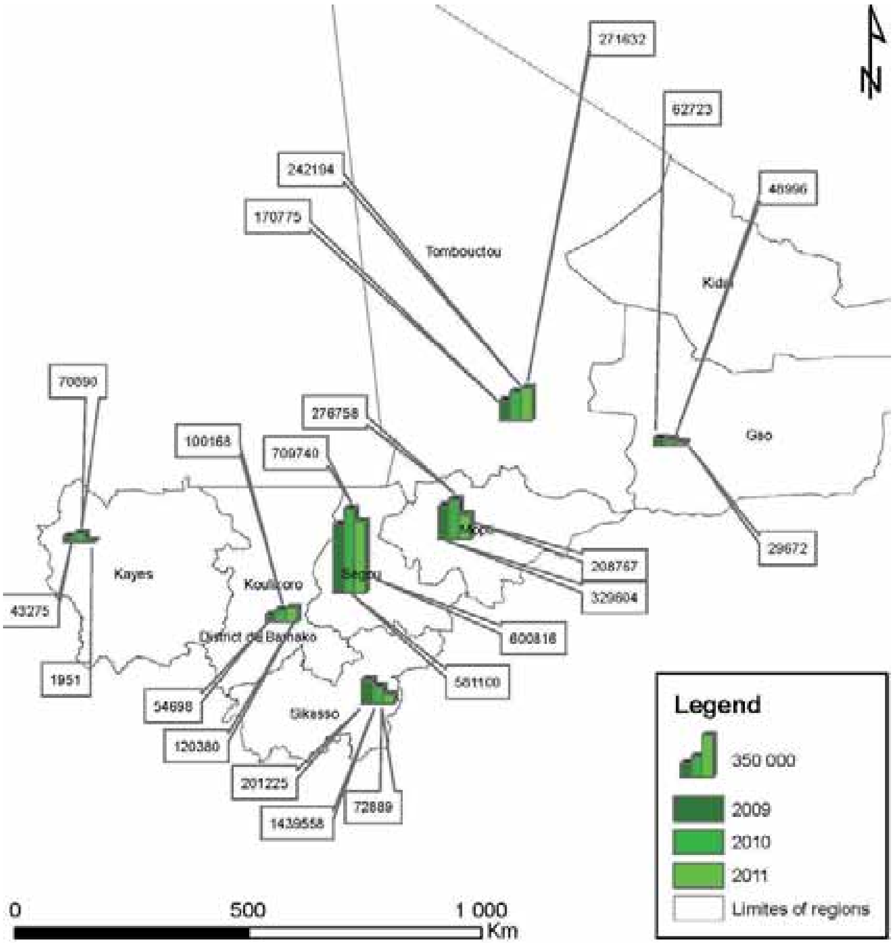

Figure 5.7. Technical potential of rice straw for energy per region in 2009-2011

6 Production of rice in Office du Niger

Office du Niger (ON) is the most important rice cultivating area in Mali, and the area with the highest concentration of rice straw. Utilization of rice straw for energy in Mali will therefore most likely start here. In order to get a thorough understanding of the present and future potential of rice straw in ON, this chapter has therefore been dedicated to a comprehensive description of rice production in ON comprising its history, its current agricultural practices, and the future plans.

6.1 Office du Niger in a historical context

Office du Niger was founded in 1932 as a state owned entity, with the objective to supply the French colonial power with cotton and rice. Plans were ambitious, aiming at almost one million ha to be developed (Schreyger 2001).

ON started up with production of cotton, but cotton was gradually abandoned during the years 1965-1970 as rice was introduced. However, by the end of the 1970s, the production of rice was decreasing and the equipment and infrastructure was in decay, whereupon the World Bank and a wide group of donors engaged in a large rehabilitation programme (Slob 2001). Alongside technical and financial support for rehabilitation of the infrastructure such as canals, draining systems etc., dramatic economic and institutional changes followed. In the years from 1986 to 1994, ON’s trade monopoly on rice and fertilizer was broken down, village associations were made responsible for water management, and central threshing and hulling was gradually replaced by decentralised and privatized threshing and hulling. The effects were impressive. In the period from 1979-1994 the yield of rice increased by 300 % and this development is continuing as will be further explained below (Tall 2001). ON is currently a very dynamic agricultural development area in Mali, which is still attracting a high level of donor intervention and recently also large private investment.

6.2 Production of rice in Office du Niger

Rice production in ON has increased by about 50 per cent in the years from 2001 to 2009. This is due to increased yields and to taking more land into cultivation. Table 6.1 and Table 6.2 show the evolution of rice production and cultivated areas from 2001 to 2009.

Table 6.1. Production of rice (paddy) in various zones in Office du Niger 2001/2009

Campaign	Macina	Bewani	Niono	Molodo	Kourou-mari	N'debou-gou	Total
2000/2001	89 643	9 860	70 765	43 399	66 295	65 725	345 687
2001/2002	82 290	11 349	76 609	46 968	69 283	65 638	352 137
2003/2004	83 346	22 274	95 401	48 633	74 995	69 798	394 447
2004/2005	88 209	28 201	101 466	50 781	77 791	72 135	418 583
2005/2006	92 695	27 775	102 970	50 945	81 486	81 750	437 621
2006/2007	92 821	37 090	91 129	50 032	85 375	73 678	430 125
2007/2008	103 588	62 350	73 987	49 201	86 328	70 668	446 122
2008/2009	117 187	68 747	81 723	51 406	106 755	87 187	513 005
2009/2010	93 722	71 558	89 557	52 755	102 643	83 856	494 092

Source: Service SIG, Office du Niger, 2010

Table 6.2. Rice production area per zone in Office du Niger 2001/2009

Campaign	Macina	Bewani	Niono	Molodo	Kourou-mari	N'debou-gou	Total
2000/2001							
2001/2002							
2003/2004							
2004/2005							
2005/2006							
2006/2007							
2007/2008		9 237	13 201	8 548	14 327	12 275	
2008/2009		9 287	13 446	8 548	14 677	12 452	
2009/2010	18 281	9 805	13 445	8 547	14 671	12 385	77 135

Source: Service SIG, Office du Niger, 2010

6.3 Future plans for rice production in Office du Niger

As mentioned above, in theory there are opportunities for significantly expanding the irrigated areas for rice and vegetable production in the ON. Figure 6.1 shows the actual irrigated area in 2000 compared to the theoretical potential of up to 2 million ha. Recent studies show that , besides capital for investment, a limiting factor will be the availability of water for irrigation from the Niger River (Zwarts and Kone 2005; Wymenga, van der Kamp et al. 2005;Vandersypen, Keita et al. 2007; Vandersypen 2007; Vandersypen, Bengaly et al. 2006).

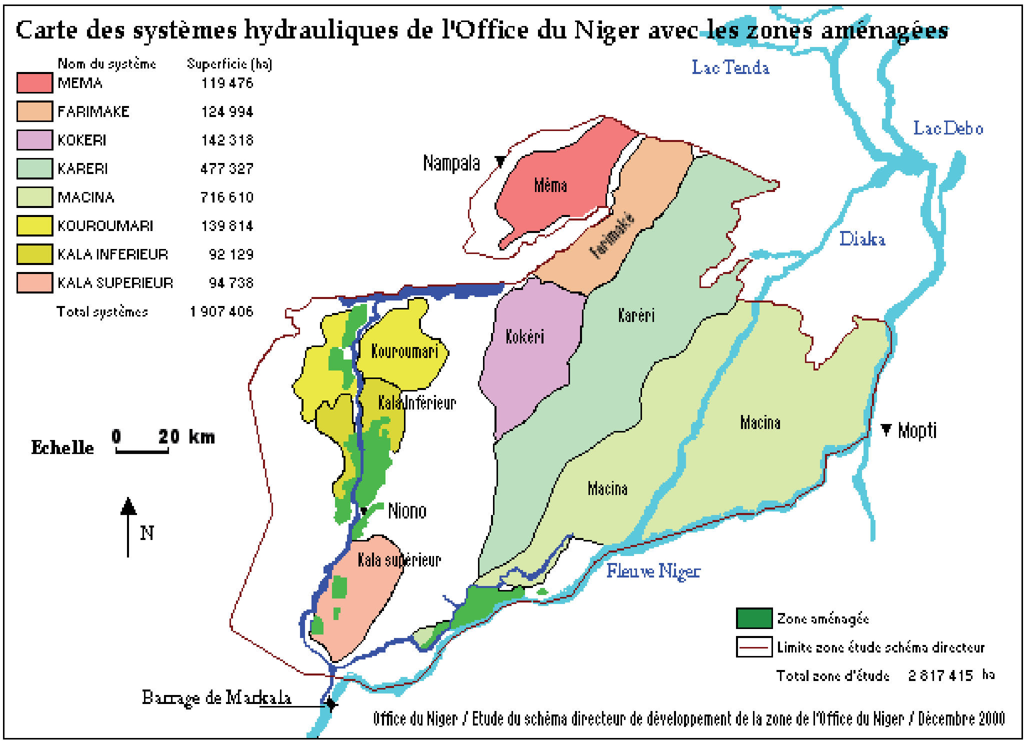

Figure 6.1. Map showing the irrigated areas in Office du Niger and the hypothetical options for expansion (Hydro-PACTE 2010)

The Malian government in cooperation with a number of donor organisations launched in 2004 a Master Plan for development of on, which is referred to as *l'Etude du Schéma Directeur de Développement pour la Zone de l'Office du Niger, (SDDZON)* (AGETIER 2004). According to the Master Plan the cultivated area of 77 000 ha, should be extended by 146 000 ha before 2020, reaching in total 220 000 ha [2]. This implies that the total production of rice and straw may increase by 300 % before 2020.

The overall potential, the cultivated area in 2004 and the planned expansion according to the Master Plan is shown in Table 6.3.

2 In addition to the extension a rehabilitation programme would improve the quality of another 28 000 ha, leaving areas which have been rehabilitated and extended to be about 202 000 ha by 2020. (AGETIER 2004)

Table 6.3. Planned extension of the irrigated area in Office du Niger (hectares) (AGETIER 2004)

Chanel	Hydraulic system	Geogra-phic area	Agricul-ture area	Irrigated 2004	Master Plan 2005-2020	Theoretical remaining potential
Depending on 'canal du Sahel'	Kala inférieur	92 129	73 700	36 244	36 684	772
	Kouroumari	139 814	111 900	14 500	43 475	53 925
	Méma	119 476	95 000	0	0	95 000
	Farimaké	124 994	100 000	0	0	100 000
Depending on 'canal Costes'	Kala supérieur	94 738	75 800	10 722	26 428	38 650
Depending on 'canal Macina'	Macina	716 610	573 000	15 712	39 121	518 167
	Kareri	477 327	382 000	0	0	382 000
	Kokeri	142 318	113 800	0	0	113 800
Total		1 907 406	1 525 200	77 178	145 708	1 302 314

The planned extensions according to the Master Plan are illustrated in Figure 6.2.

The Master Plan was adopted by the Government (*Conseil de Ministres*) in December 2008, and although the implementation of the plan has been delayed for various reasons, the expectation at a donor conference in 2010 was still to reach 78 % of- the projected extensions before 2020 (Hydro-PACTE 2010).

The Master Plan has in several ways been overtaken by events on the ground, and at the donor conference in 2010 it was revealed that in the period from 2004-2009, 645 259 ha were allocated to private companies in firm or provisional agreements (Hydro-PACTE 2010).[3]

Among those allocations are 16 000 ha in Altona, which should be developed by Millennium Challenge Corporation, including construction of 81 km tarred road, and 12 000 ha which should be developed by the member states of UEMOA (MA 2009).

3 In the presentation, reference is given to: 'Note technique sur la situation des aménagements et attributions de terres à l'ON " by Office du Niger.

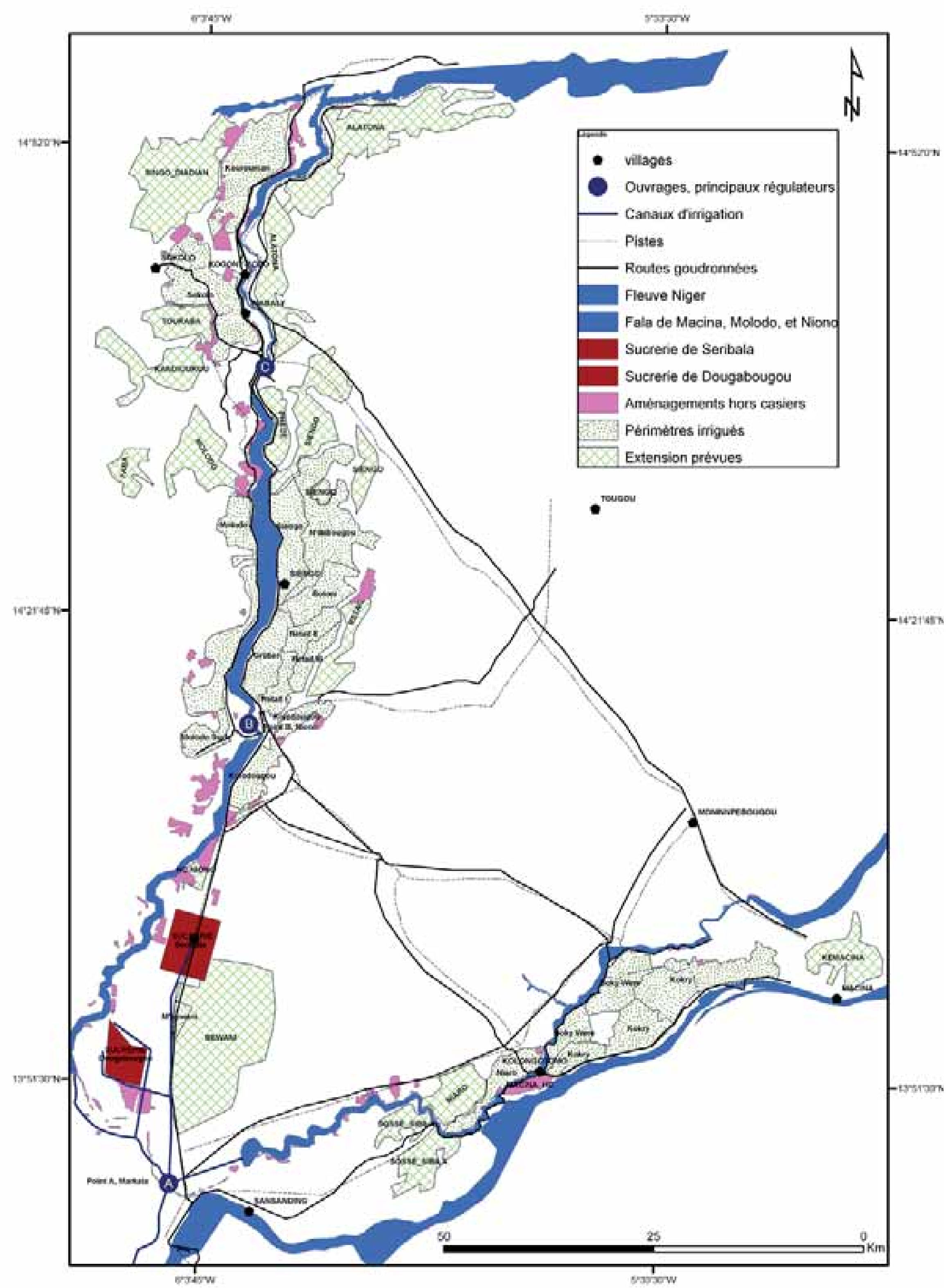

Figure 6.2. Map of ON showing cultivated areas in 2004 and planned extension before 2020 (AGETIER 2004)

More details are given a research paper from Cahiers Agricultures (Brondeau 2011), and in a report from the research institution, the Oakland Institute in 2011 (Baxter 2011). Based on information from Office du Niger, Baxter (2011) provides a list comprising allocation of 544 567 ha for private agricultural development.[4]

The report brings a detailed description of the following 4 projects:

> Malibya: In June 2008, Malibya was conceded 100 000 ha for production of hybrid rice, livestock and tomato processing, located west of the town Macina. The project will include construction of an irrigation canal between Kolongotomo and the main project site in the Boko Were zone. Investor Malibya, a subsidiary of Libya Africa Investment Portfolio.
>
> Tomota: Plan of developing 100 000 ha for producing oil crops such as sunflower, soya, peanuts, karité and jatropha. The area is places at the western boarder of the Malibya lease, including Monipébougou, Macina and Ténenkou. Investor: Huicoma, which main shareholder is the Malian owned, Tomota Group.
>
> Petrotech: Plan of developing 10 000 ha for oil-producing plants in the Kareri hydraulic Zone. Investor: Petrotech-ffn Agro Mali-SA, a sister company of the Egypt based research and development centre Petrotech-ffn in Egypt and a subsidiary of Petrotech-ffn USA.
>
> Moulin moderne du Mali. 20 000 ha for wheat production in the Upper Kala hydraulic zone. Investor: Group de Societes Moulin Moderne du Mali (GDCM) and Complexe Agropastoral in public private partnership with the Malian State. First 7,400 ha covered by lease.

The main extensions envisaged are shown in Figure 6.3, which is based on a map from Office du Niger from 2010.

4 Referring to: i) Office du Niger, DAGF/SCF Plan de zonage des aménagements et projections, October 2010; ii) Office du Niger, Direction Générale, 16 October 2010. Situation récapitulative des attributions des terres en bail dans la Zone Office du Niger.

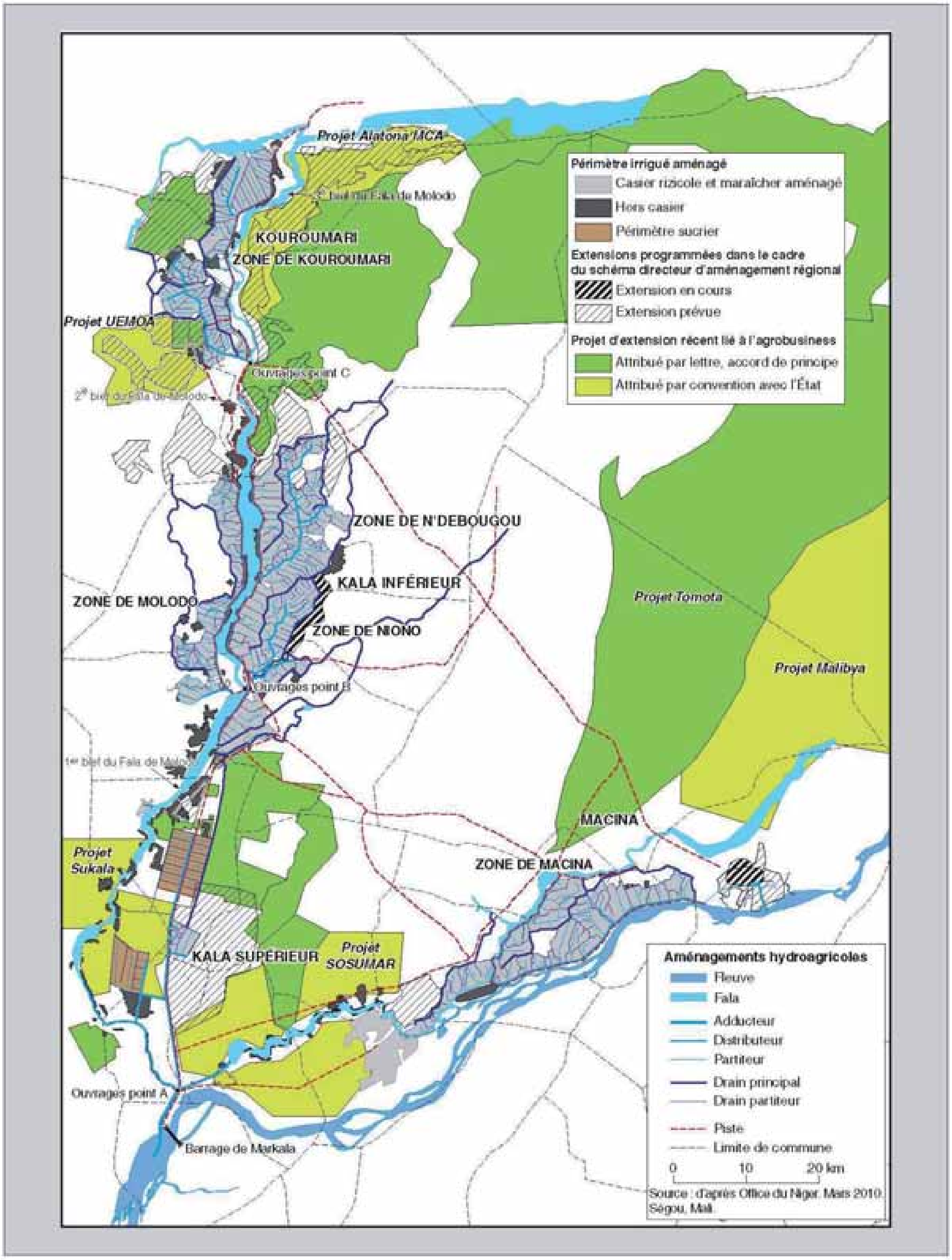

Figure 6.3. Map showing envisaged extensions (Brondeau 2011 based on Map from ON, 2010)

6.4 Conclusion

The level of rice production in ON was around 500 000 tonnes in the years 2009 to 2010, based on an average yield of 6.4 tonnes/ha. According to the Master Plan the cultivated area is expected to increase to 220 000 ha before 2020, which means that the production of rice within the Office du Niger may reach 1.4 million tonnes of paddy using a conservative estimate that yields will remain constant at an average of 6.4 tonnes per ha.

It is so far difficult to judge what the impact the large land allocations will have on the future amount of rice produced in ON. According to the list from Oakland Institute rice will mainly be produced by the Malibya project, which will also produce livestock and tomatoes. This may increase the rice production by a further 0.3-0.6 million tonnes, contingent on the share of rice production (50 or 100 %).

On the other hand, although most of the allocations are situated in the hydraulic systems of Mema, Kokeri, Kareri and Macina (see map in Figure 6.1), and therefore outside the immediate spatial scope of the Master Plan, these land allocations may have a negative impact on the future plans for rice production, (including the master plan) as the availability of water may be a limiting factor.

7 Sustainable potential of rice straw for energy in office du Niger

This chapter presents the assessment of the sustainable potential of rice straw for energy in ON. The current practice of harvesting and use of rice straw in ON is presented followed by a presentation of the survey results and a discussion of its uncertainties. The final section provides the results of the assessment.

7.1 Current practice of harvesting and use of rice straw

The production of rice is still based on a high level of manual labour input. The rice is harvested by sickle and left in the field for drying. From here it is manually transported to the dikes, where it is stored in piles, until it is threshed by mobile threshers. Due to problems with water management and draining, rice fields are often still wet and mechanization of harvesting and transport of straw in the fields is difficult.

Figure 7.1. Mobile thresher in the field (left) and threshed straw in a pile close to the dike (right) (photo: Ivan Nygaard)

The threshed straw is the resource which is conceptualized as the technical potential, and which is estimated by using the statistical data for rice and multiplying by the straw-to-grain ratio. The technical potential is currently either burnt or used as i) feed for own cattle, ii) feed for cattle of others, including neighbours and cattle on transhumance, or iii) incorporated into the soil. The current fraction used for the three purposes has been estimated by the survey. The result is shown in section 7.2.

The stubble left in the field is currently partly burned, partly incorporated into the soil to improve the organic matter in the soil, but mainly used to feed grazing animals, as explained in the next section.

Rice straw as cattle feed

In ON there were about 300 000 heads of cattle, (of which 43 000 draught oxen) in 1998. To this comes about 16 000 donkeys for transport (Le Masson, Sangaré *et al.* 2001). During the rainy season most of the cattle are on transhumance in the pastoral zones around the irrigated areas in ON, but as shown in Table 7.1, the animals return to the irrigated areas during the dry season from December to May/June. During this period they graze stubble in the fields as well as feeding on piles of threshed straw, with the benefit that they leave the manure for fertilizer.

Table 7.1. Seasonal variation of the presence of cattle in the rice fields

Tableau 1. Présence du bétail sur les casiers dans le Kala inférieur, selon les mois.

Animaux	Janv.	Fév.	Mars	Avril	Mai	Juin	Juil.	Août	Sept.	Oct.	Nov.	Déc.	Total (mois)
Bœufs de trait	C	C	C	C	C	C	C	C	T	T	T	T/C	8,5 C et 3,5 T
Autres	C	C	C	C	C	C/T	T	T	T	T	T	T/C	6 C et 6 T

C, bétail sur casier ; T, bétail en transhumance.

The cattle in the ON belong not only to the farmers themselves. During the dry season the relative abundance of feed stock in the delta has traditionally attracted transhumant herders from the regions north of ON.

Figure 7.2. Cattle grazing stubble in the fields of Niono, November 2011 (Photo: Oumar Fatogoma Traoré)

The increasing pressure on fodder, partly due to decrease in rainfall, but mainly due to increase in the number of cattle, means that the large irrigated area in ON is an attractive destination for transhumant herders with their cattle.

Grazing of stubble by own and transhumant cattle is part of a long traditional cohabitation of herders and farmers, see Figure *7.2*. The manure left in the field is a valuable input of organic fertilizer for the farmers, but the growing amount of cattle in the region increasingly creates tensions and conflicts between farmers and herders, when transhumant cattle are destroying crops. These conflicts are also increasing in Office du Niger. This is mainly due to the increasing practice of bi-seasonal farming, i.e. the increasing practice of cultures de *contre saison.* This means that cattle can cause a lot of problems by destroying crops in cultivated fields, be it vegetable gardening, rice or other crops.

7.1.1 Burning of straw in the field

Burning of straw in the field is an old practice which has been strongly opposed by the agricultural extension workers from Office du Niger, in order to reduce the risk of bush fires, reduce local air pollution and to use the straw as a fertiliser (composting) or for incorporating it into the soil.

According to the questionnaires, a considerable amount of straw (between 2 and 22 % depending on the zones) is still burned in the field. According to interviews with farmers and extension workers, straw is mainly burned by the farmers to get read of threshed straw piling up on the dikes and to reduce the risk of filling up the drainage system with straw. A smaller amount of threshed straw is also burned to provide nutrients for vegetable gardening and for rice nurseries.

Besides burning of threshed straw, also stubble is burned in the field to combat weeds and to make the cultivation of the next crop easier.

Figure 7.3. Burning of straw in the fields in Office du Niger, November 2011 (Photo: Oumar Fatogoma Traoré)

7.2 Survey of current use of rice straw in Office du Niger

The sustainable potential of rice straw is defined in this study as the amount of straw which is currently burned in the field.

In the present context, using the amount of straw for energy which is currently used as fodder for cattle is not considered to be socially and economically sustainable.

On the other hand, there are obviously only positive impacts of using the straw already burned in the field for energy purposes, hence limiting the local air pollution through cleaner combustion in a boiler, and substituting the use of fossil fuel, such as for electricity production. The impact of using the straw which is currently incorporated into the soil is less obvious. The study of environmental impact of incorporating the straw into the soil, reported in Annexe A, concludes that using the rice straw as fuel would not have severe implications for the soil quality in the study area. In this study we have, however, only included the fraction burned as the sustainable resource.

7.2.1 End use of threshed straw

The end-use of the threshed straw was estimated through a survey in which 300 farmers were asked about their current use of threshed straw, as already described in chapter 4. The results of the survey covering four selected zones in ON and one zone in Office du Mopti are presented in Table 7.2.

The farmers were asked to estimate the share of their threshed straw falling into the 5 categories. The results are calculated as a weighted average of the use at each farm included in the interviews. About 12 % of the rice production in the zones was covered by the interviews.

Table 7.2. Current use of threshed rice straw in Office du Niger and in Office du Mopti

Zone	Inter-views	Burnt in the field	Incorpo-rated into soil	Fodder for own cattle	Fodder for other cattle	Other uses	Total
Niono	62/20	22%	11%	31%	35%	-	100%
N'debougou	61	19%	10%	12%	59%	0%	100%
Molodo	60	12%	7%	18%	61%	2%	100%
Kouroumari	None	18%	9%	20%	52%	1%	100%
Bewani	None	18%	9%	20%	52%	1%	100%
Macina	80	2%	35%	38%	21%	4%	100%
Mopti Nord	40	11%	0%	24%	64%	1%	100%

The zones Niono, N'debougou and Molodo were selected for investigation of use of straw, as the town of Niono, was chosen to be used as the site for a prefeasibility study of a straw fired power plant.[5] Macina and Mopti Nord were included in order to get a broader view of the use of rice straw in other regions. Macina differs from Niono, N'debougou and Molodo, in terms of being more prone to pressure from transhumant cattle, and Office du Mopti has a different production system with much lower yield.

The empirical study does not provide any information on the use of straw in the zones Kouroumari and Bewani, which are situated north and south of the three zones Niono, N'debougou and Molodo, see Figure 6.2. As the two zones have agricultural characteristics which are similar to Niono, N'debougou and Molodo, the best estimate for the use in the two zones would be an average of the use in Niono, N'debougou and Molodo. These figures are presented in Table 7.2

7.2.2 Discussion of uncertainties and potential bias

The most likely uncertainties and bias in this study are related to:

- Representativeness of interviewees
- Interviewees understanding of the questions
- Interviewers understanding and interpretation of the questionnaires
- Interviewer bias
- Strategic answers

These uncertainties are discussed below, along with their effects, especially on the share which is burned and the share which is incorporated into the soil.

Representativeness

The research aimed at stratification according to size of farms and according to geographical spread in the five zones included in the field-study. This seems to be achieved. No tests have been made for representativeness with respect to size of farms, income level, education level, organizational level or ethnicity, but no signs on such bias have been found.

Interviewees understanding of the questions

It is a challenge to make illiterate farmers estimate the shares of their production of straw used for 5 different purposes. Various participative appraisal techniques were proposed, such as giving the farmer 10 sticks, or 10 marbles for illustrating the shares. It is not clear to what extent such techniques were actually used during the interviews.

Interviewers understanding and interpretation of the questionnaires

The interviewers went through several hours of training and in the case of Niono, N'debougou and Molodo; test interviews were conducted and discussed to give the interviewers the same understanding of the questionnaires. The level of training was lowest

5 This was mainly due to the fact that the three zones constitute a major contiguous area with rice production with Niono as a natural centre. This would facilitate the transport of straw from the field to the plant and provide opportunities for both local use of electricity from the plant and transmission of electricity to other parts of Mali through the new transmission line between Niono and Segou.

in Macina, where the interviewers were trained by a trainer and highest in Mopti Nord, where the interviews were carried out by the two consultants from MFC, who were responsible for the field-study.

Interviewer bias

Interviews were planned to be conducted by two to four interviewers per zone in order to reduce an interviewer bias from different interpretation of the questionnaires, different pre-understanding of the subject matter and differences in interview practice. Due to various practical reasons, at the end only one interviewer conducted interviews in each of the zones, Niono, N'debougou and Molodo. There is hence a risk that the observed variation in the results between Niono, N'Debougou and Molodo, may be the result of an interviewer bias rather than a difference on the ground. It might therefore for some purposes be reasonable to use the average for the three zones, which are contiguous. The average for the three zones is used as estimates for the zones Kouroumari and Bewani.

Strategic answers

Strategic answers may reflect the official policy rather than the practice on the ground. It is therefore important to analyse to what extent the presence of official representatives may have influenced the answers.

In all cases representatives from Office du Niger either conducted the interviews or were present during the interviews. This was difficult to avoid in this context and it was accepted as questions were considered not to be sensitive. However, as explained further below, strategic answers turned out to give a serious bias to the first results of shares burned in the field.

Uncertainties on the shares burned in the field

The first analysis of data produced the remarkable result that, while less than 1 % of the straw was burned in Niono, as much as 19 and 12 % was burned in Molodo and in N'debougou. There were no good reasons why this should be the case, so the most obvious explanation was that the difference should be related to the interviewer. It was therefore decided that the field study manager from MFC should conduct 20 test interviews in Niono, and at the same time try to identify a reason for the difference, if any.

Interestingly, the new 20 questionnaires revealed that 22 % of the straw was currently burned in Niono. According to the information collected, farmers apparently had answered strategically that they were not burning straw in the field, because the interviewer was seen as a representative of ON, which had encouraged the farmers not to burn straw and enforced a ban on burning. The results for Niono presented in Table 7.2 are therefore based on the 20 new questionnaires from the follow up. Based on this example, it would be reasonable to conclude that the amount currently burned is slightly underestimated as answers may be influenced by the official campaign against burning of straw in the field.

Uncertainties on the amount incorporated into the soil

Part of this study was an assessment of the environmental impact of incorporating straw into the soil, as presented in Annexe A. This assessment is based on field work conducted in Macina in 2010. In the search for fields with varying amounts of straw incorporated into the soil, the researcher found that few farmers actually spread the threshed straw on the field with the objective of incorporating it into the soil. A few mixed the straw with manure to make compost before spreading it. This finding by the researcher is in contrast to the results of the questionnaires according to which 35 % of the straw is incorporated into the soil. One possible reason for this difference may be that the interviewer (in this case trained by a trainer), may have misunderstood the question and asked about the use of all the straw (including stubble) instead of threshed straw as intended.

The fact that 35 to 45 cm of stubble is normally left in the field in Macina can explain that the farmers have considered that 35 % of the straw including stubble is left in the field and incorporated into the soil. If this is correct, it is likely that the share incorporated into the soil may also be overestimated in other zones, due to a similar misunderstanding – either systematically by the interviewer or occasionally by the farmers.

7.3 Sustainable potential of straw for energy in Office du Niger

The sustainable potential of straw for energy in ON is calculated on the basis of the average of the yield of rice paddy in the years 2009 and 2010. The technical potential is defined as the amount of straw threshed and is calculated by using the uniform straw-to-grain ratio of 0.75 for all zones. The sustainable resource is defined as the share of harvested straw which is currently burned. This share varies for the zones and is estimated as described in section 7.2.1.

Table 7.3. Technical and sustainable potential of straw for energy in Office du Niger (tonnes/year)

Zone	Macina	Bewani	Niono	Molodo	Kourou-mari	N'debou-gou	Total
Harvest avr. 2009-2010	105 455	70 153	85 640	52 081	104 699	85 522	503 549
Straw-to-grain ratio	0.75	0.75	0.75	0.75	0.75	0.75	0.75
Technical resource	79 091	52 614	64 230	39 060	78 524	64 141	7 661
Share being burned	2%	18%	22%	12%	18%	19%	15%
Sustainable resource	1 582	9 471	14 131	4 687	14 134	12 187	56 191

The sustainable resource for the three zones (Niono, N'debougou and Molodo) next to the town of Niono is about 31 000 tonnes of straw per year. The technical resource for the three zones is about 167 000 tonnes of straw per year.

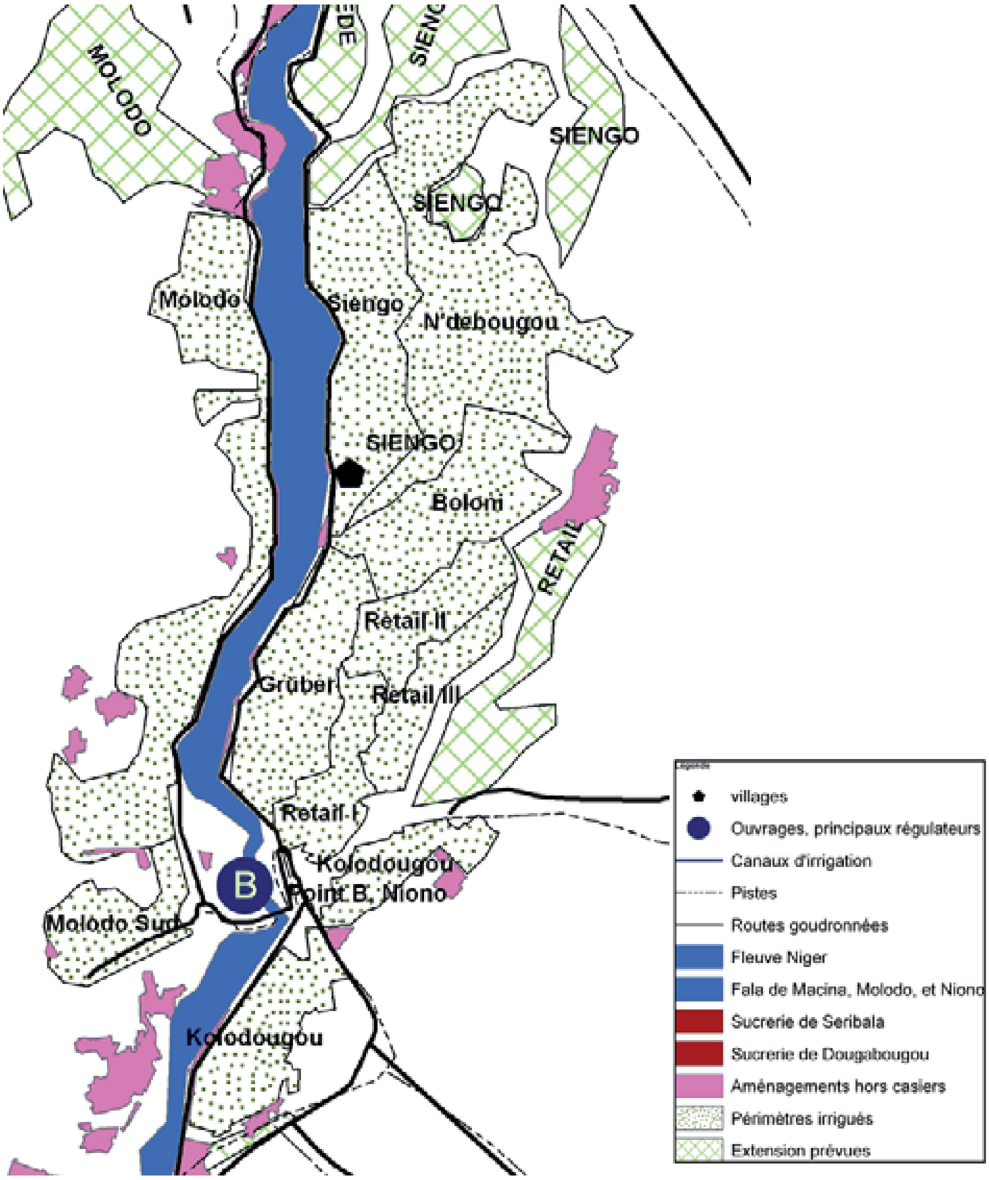

Figure 7.4. The three zones Niono, N'debougou and Molodo, next to the town of Niono, situated right of the signature B. Drawing based on maps from the Master Plan (AGETIER 2004)

The three zones Niono, N'debougou an Molodo situated around the town of Niono are shown in Figure 7.4 below. The zone of Niono comprises the *casiers* Kolodougou, Grüber, Retail I, Retail II and Retail III. The zone of N'debougou comprises the *casiers* Boloni, Siengo and N'debougou, and the zone of Molodo comprises the *casiers* Molodo sud and Molodo North on the west side of the Fala de Niono.

According to the Master Plan the current cultivated are at ON of around 77 000 ha in the years 2009 to 2010, is expected to increase to 220 000 ha before 2020. This means that the production of rice within the ON may reach 1.4 million tonnes using a conservative estimate that yields remain constant at an average of 6.4 tonnes per ha. The future sustainable resource can only be estimated by a high level of uncertainty, but given: i) production of 1.4 million tonnes of rice per year, ii) a constant straw-to-grain ratio of 0.75 and iii) a constant share of straw burned at 15 %, the technical potential of straw in ON in 2020 will be 1.05 million tonnes per year and the sustainable potential will be 158 000 tonnes per year.

8 Waste resources from processing of rice

The assessment of waste resources from agro-industries is beyond the scope of the present project. Throughout the project, however, several requests have been made for including rice hulls (or husks) in the assessment, and we have therefore decided to include a desk-study of the resources of risk hulls available for energy purposes.

Major insights in this regard are drawn from a study of rice hulls for electricity production financed by USAID in 2005 (USAID 2005). This study will be updated with the latest data available regarding the rice production in Office du Niger, and with findings during the fieldwork.

8.1 Hulling of rice

Until 1984, threshing and hulling of rice was entirely conducted at central threshing and hulling installations owned and operated by the Government owned Office du Niger. As part of the privatisation process that started with the ARPON project in 1984, the farmers associations were given small mobile threshers, and by 1990 83.000 out of 144.000 tonnes of paddy was processed by mobile threshers. (Aw and Diemer 2005; 26). Likewise mobile hullers were donated to women's groups in 1988 to reduce women's burden but more important to weaken ON and to break its monopoly on sales of rice. Mobile threshers and mobile hullers have since been taken over by mainly private entrepreneurs, and as a result of the privatisation process, ON closed its threshing and hulling activities in 1992. This also led to the closure of three thermal gasifiers in Molodo, Dogofiri and N'Debougou and a boiler and steam turbine unit in Secou, which were all using rice hulls produced at the mills for electricity production for internal use (Mahin 1989;USAID 2005). The Chinese built thermal gasifiers (160 kW_{el}) at Dogofiri and N'debougou were in operation since the beginning of the 1970s and due to the experienced reliability of the plants, a third plant was installed in Molodo in 1986 supported by the GTZ (Mahin 1989). According to a review by Stassen (1995) a main concern with these plants was unsolved environmental problems from wastewater contaminated with tar from the gas cleaning.

Table 8.1. Status of former ON owned rice hulling mills in 2004 (USAID 2005)

Location	Owner	Year Built	Capacity	Distance to Segou	Notes
1. Dioe/Segou	Bakore Silla	(?)	(?)	50 Km	Closed[1]
2. Segou City	Modibo Keita	(?)	50 T/day	0 Km	Working[2]
3. Segou City	Modibo Keita	(?)	75 T/day	0 Km	Closed
4. Kolongo du Macina	Aliou Boubacas Diallo	1948	1200 T/yr	91 Km	Closed
5. Molodo/Niono		1950	30,000 T/yr	113 Km	Closed[3]
6. Dogofери/Diabali		1968	21000 T/yr	80 Km	Closed
7. Debougou		1976	21000 T/yr	120 Km	Closed
8. Sevare/Mopti	Modibo Keita	1973	6 ~ 9000 T/yr		Not working[4]

8.2 Estimation of technical potential for rice hulls

According to Koopmans & Koppejan (1998) residue-to-product ratios for rice hull range from 0.2-0.35. In their study for the FAO they have used a residue-to-product ratio of 0.267 referring to a most quoted study of Bhattacharya, Pham (1998). Tripathi, Iyer *et al.* (1998) uses a residue-to-product ratio of 0.25 for India, and in a recent study Shackley, Carter *et al.* (2012) anticipates that rice hulls amounts to about 20 % of paddy production.

The USAID (2005) study uses a residue to crop ratio of 0.21. Given this figure and given an annual production at national level of 2 million tonnes of paddy in 2008-2011 and a planned production at national level of 4 million tonnes of paddy in 2020 (Figure 5.3), the technical potential of rice hulls for energy is currently around 400.000 tonnes, and the technical potential according to the plans will be about 800 000 tonnes by 2020.

Given an annual production at Office du Niger of around 500,000 tonnes in the years 2009 to 2010, with a potential increase to 1.4 million tonnes of paddy before 2020 as estimated in section 6.4, the current technical potential of rice hulls for energy at the Office du Niger is about 100.000 tonnes, potentially increasing to 280.000 tonnes by 2020.

8.3 Estimation of sustainable potential for rice hulls

Estimation of the sustainable potential of rice hulls is less straightforward, as the literature only provides unclear indications of current use of rice hulls. Also the use of rice hulls will be contingent on the future application of rice hulling technologies.

The portable rice hullers which are currently used, produce a mixture of broken rice, hulls and bran (USAID 2005). According to a recent study by USAID (2009) assessing the rice value chain, the portable hullers are quite inefficient and operate with a 50-60 % net yield. The relatively high amount of broken rice in the residue, means that it has a relatively high nutrient value for cattle, compared to 'pure' rice hulls, and according to USAID (2005) this fraction is currently returned to the farmers as animal feed. Nevertheless, as the picture in Figure 8.1 shows, there are substantive amounts of this residue, which is actually stored in big piles close to the huller and which is partly burned and partly left to rot.

Figure 8.1. Mobile rice huller (left) and pile of rice hulls (right) at the village N4 in Niono (photo: Ivan Nygaard, 2010)

In order to reduce the losses and improve the quality of processed rice, mini rice mills are gradually being established in Office du Niger. USAID (2005) refers to 10 such mini rice mills operating at Seriwali, only about 7 km from Niono, and refers to plans of establishing another 10 rice mills in the area. According to the same source the mini rice mills are of the rubber-roll sheller/steel-polisher type, and are capable of producing a better quality of milled rice (less broken grains), while at the same time producing two by-products – hulls (husk) and bran. The 10 mini rice mills produces about 15 000 tonnes of rice hulls per year, which will be available for energy purposes, as pure hulls due to their high silica content are not suited for cattle feed.

To the extent that mini rice mills will take over the rice hulling market in Office du Niger, the sustainable potential of rice hulls will equal the technical potential mentioned in section 8.2 above.

Another development trend is that rice will again be processed at large centralised plants in Segou or elsewhere. This means that the large technical potential of rice hulls may be available at centralised plants, where it could be used for production of electricity as it was the case before the current privatization and decentralisation. The USAID (2005) study provides some initial calculations exploring this option.

9 Residues from sugar production

Sugar has been produced in ON since the first plantation was established in 1962 and the first sugar factories in Dougabougou and Seribala were constructed in 1965 and 1974 by assistance from the People's Republic of China (Schreyger 2001)

Under the name of SUKALA, the two factories have since 1996 been owned by a joint venture between the Malian government (40 %) and China Light Industrial Corporation for Foreign and Technical Cooperation (CLETC) (60 %). Since 1996, production has increased from 23 000 to 39 000 tonnes of sugar per year cultivated on an area of 5700 ha (SUKALA 2010).

According to Baxter (2011) SUKALA has in 2009 been attributed 20 000 ha of land to increase the production of Sugar and to start a production of bioethanol. Location of existing plantations in Siribala and Dougabougou and the expansion of 20 000 ha is shown in Figure 9.1. Location of the existing plantations is also shown in Figure 6.2 and Figure 6.3

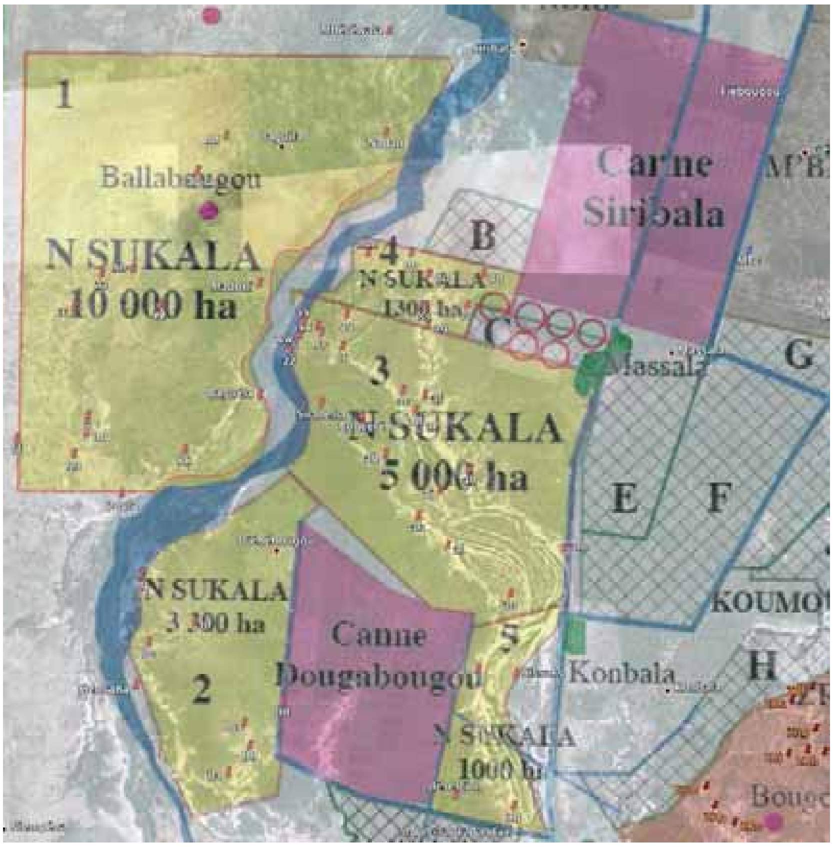

Figure 9.1. Location of existing and future areas cultivated by SUKALA (Source: Office du Niger)

According to an article on Mali Web September 2011 the first 14 000 ha was already at that time under cultivation and a new factory was expected to be in operation early 2012. The annual production is estimated to 100 000 tonnes of sugar per year and 9.6 million litres of alcohol (Mali Web 2011).

Another project, SOciete SUcriére de MARkala (SoSuMAR) has been under development for some years and according to an interview with the management in February 2012 (SOSUMAR 2012), the company was at the time in the phase of concluding financial agreement, and it was expected that the first sugar would be produced in 2015 and that full production would be achieved in 2018. The main shareholder in the company is the largest sugar company in Africa, Illova Holding in a public private partnership with the government of Mali (6 %). The project involves a fair amount of donor support and financial involvement from a number of investment banks, among others the African Development Bank (SOSUMAR 2012; Baxter 2011)

In 2009, the company was attributed 17000 ha with the right to extension on a long-term lease contract. According to the lease contract of the 17000 ha, the annual production should reach 195 000 tonnes of sugar/year and 15 million litres of ethanol/year. The potential for extension is unclear but the map from Office du Niger shows 39 000 ha, see Figure 6.3 (Baxter 2011).

9.1 Residues from sugar production

Residues from sugar factories in terms of bagasse are generally burned for production of process steam and power in the factories, but often with low efficiency as excess power cannot be sold to the grid. Institutional reform in some countries, as e.g. Mauritius has significantly increased the contribution of electricity from sugar factories to the national grid (Deenapanray 2009). Information on existing and planned electricity production from bagasse in Mali is further elaborated below.

Another potential residue from sugar production is the leaves. In cases like Mali, where sugar canes are harvested manually, the leaves are burned before harvest in order to reduce weight and to combat animal pests. In cases with mechanical harvest, the leaves will be left in the field unburned and can be used as a potential resource for electricity production. In the case of SOSUMAR, 70 % will be harvested manually and 30 % mechanically, but this may change over time, as manual harvesting of sugar cane is hard, dirty and dangerous (SOSUMAR 2012). Although estimation of the precise amounts of resources is outside the scope of this study, the leaves from sugar cane could be an important future resource, which could be used in combination with straw and rice hulls for energy production.

9.2 Existing and planned power production

According to the interview with SoSuMAR a bagasse-fired power plant of 30 MW_e will be established for own consumption of process energy and electricity (27 MW_e) and for supplying electricity to the grid (3 MW_e). A power-purchase agreement has been concluded with Energie du Mali (EDM). The power-purchase agreement is the first of its kind in Mali, but no details have been revealed (SOSUMAR 2012).

According to the interview above, SUKALA is currently producing 5 MW_e from bagasse for own consumption, and a new power plant of 15 MW_e is planned in connection with the planned increase in production to 100 000 tonnes of sugar per year (SOSUMAR 2012).

9.3 Conclusion

The development in the sugar industry in ON provides interesting opportunities for the future use of straw and rice hulls from the area. Although the expansion of sugar industries takes up land and water in ON, which may hinder expansion of rice production, it may in the future provide substantive amounts of raw material for a power plant in terms of leaves. Not least, may it provide access to know-how and technology for steam-based power plants, which can be important for establishing a rice straw fired power plant in the area.

10 Technical potential of cotton stalks for energy at national level

The aim of this chapter is to assess the technical potential of cotton stalks for energy production at national level. The technical potential is defined as the actual amount of cotton stalks from cotton production in Mali.

The first section in this chapter provides detailed statistical information on cotton production per region and per CMDT zone provided by FAO Stat and by CMDT. The following section provides an estimate of the historical and the actual technical potential of cotton stalks, by using the estimated residue-to-product ratio for cotton stalks described in section 3.2.2.

The sustainable potential of cotton stalk for energy production in the CMDT zone of Koutiala is described in chapter 11.

10.1 Production of cotton in Mali

The evolution of cotton production and cultivated cotton area in Mali is shown in Figure 10.1. Cotton production peaked in the years from 2002 to 2004 at a level of 600 000 tonnes of cotton (lint), but due to falling farm-gate prices the cultivated area and production fell dramatically from 600 000 tonnes in 2004 to about 200 000 tonnes in 2008. Since then the market seems to have recovered a bit and the latest statistical information from 2010 (agricultural season 2010/2011) shows a total production of 261 000 tonnes.

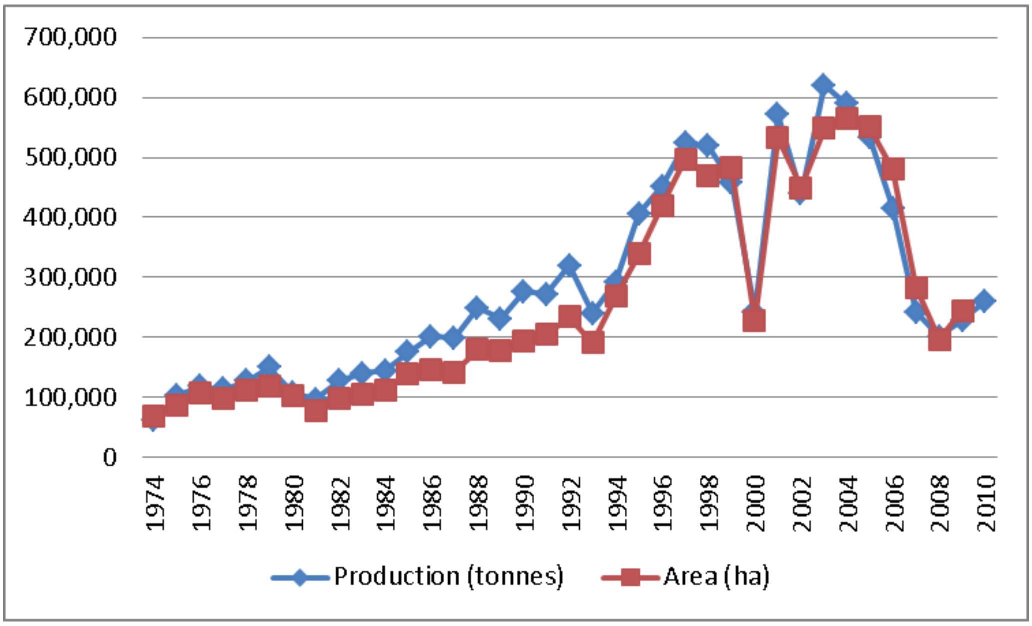

Figure 10.1. Cotton production (lint) and cultivated areas from 1974 to 2010. (CMDT and FAO statistics 2012 www.countrystat.org)

Cotton is mainly grown in the regions of Sikasso, Koulikoro, Segou and Kayes. The regional distribution of cotton production is shown in Table 10.1 and in Figure 10.2. Detailed statistical information on cotton production is presented in Annexe B.

Table 10.1. Production of cotton (lint) from 1984-2010 (tonnes) per region (FAO statistics 2012, www.countrystat.org)

Year	Sikasso	Koulikoro	Segou	Kayes	Total
2000	158 119	23 054	39 292	22 307	242 772
2001	345 100	134 935	56 000	35 300	571 335
2002	292 341	88 200	23 926	35 255	439 722
2003	404 240	126 406	51 583	38 436	620 665
2004	370 319	130 237	42 143	47 081	589 780
2005	340 765	110 043	39 607	43 728	534 143
2006	262 111	80 596	34 366	37 892	414 965
2007	164 298	42 770	14 156	21 015	242 239
2008	134 815	28 698	23 833	15 350	202 696
2009	160 700	47 000	19 500	9 200	236 400
2010					261 000

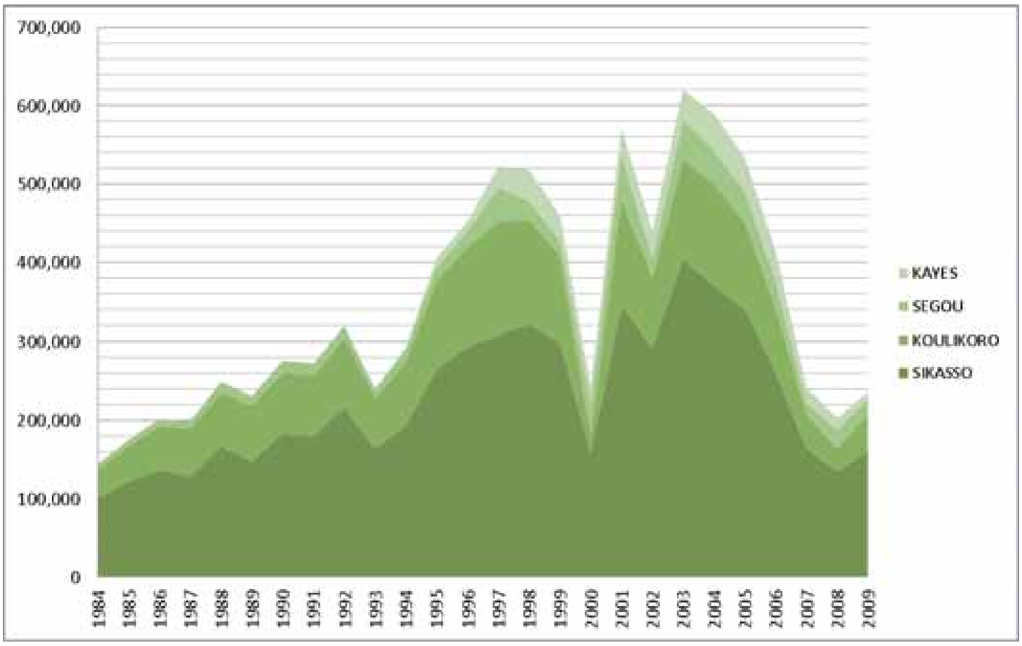

Figure 10.2. Production of cotton (lint) per region in the period from 1984 to 2009 FAO statistics 2012, www.countrystat.org)

It is worth remarking the large variation in cotton production over time. The important decline in 2000 is the result of a farmers boycott of cotton production due to discontent with the conditions offered by CMDT (Theriault 2010; MDSSPAR 2009). The important reduction in production in 2006 to 2009 is mainly due to reduction in off farm sales prices, as shown in Figure 10.3. The decline in off-farm sales prices is explained by a decline in world-market prices due to subsidies to cotton production in the North (MDSSPAR 2009), but as cotton fibres are generally traded in USD, the exchange rate between USD and EUR plays an important role for the price setting in Francophone West Africa (Levrat 2009). The exchange rate between USD and EUR is shown in Figure 10.4.

This historical variation in cotton production means that the authors of this report have been reluctant to make any projections of future cotton production.

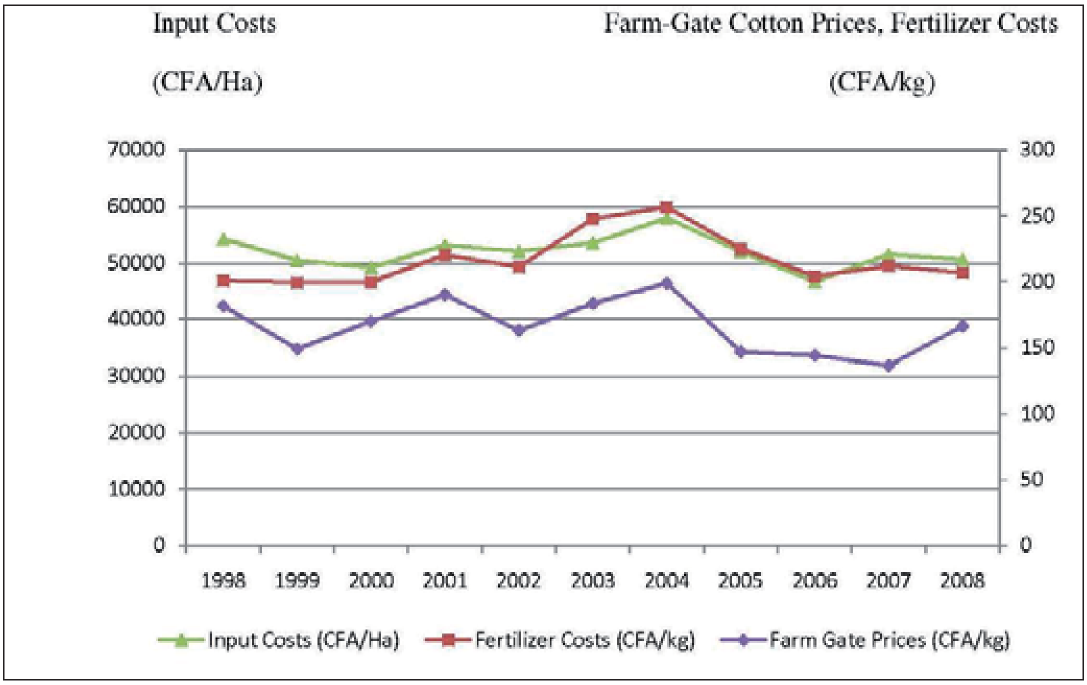

Figure 10.3. Farm-gate cotton prices, fertilizer costs and input costs (Theriault 2010)

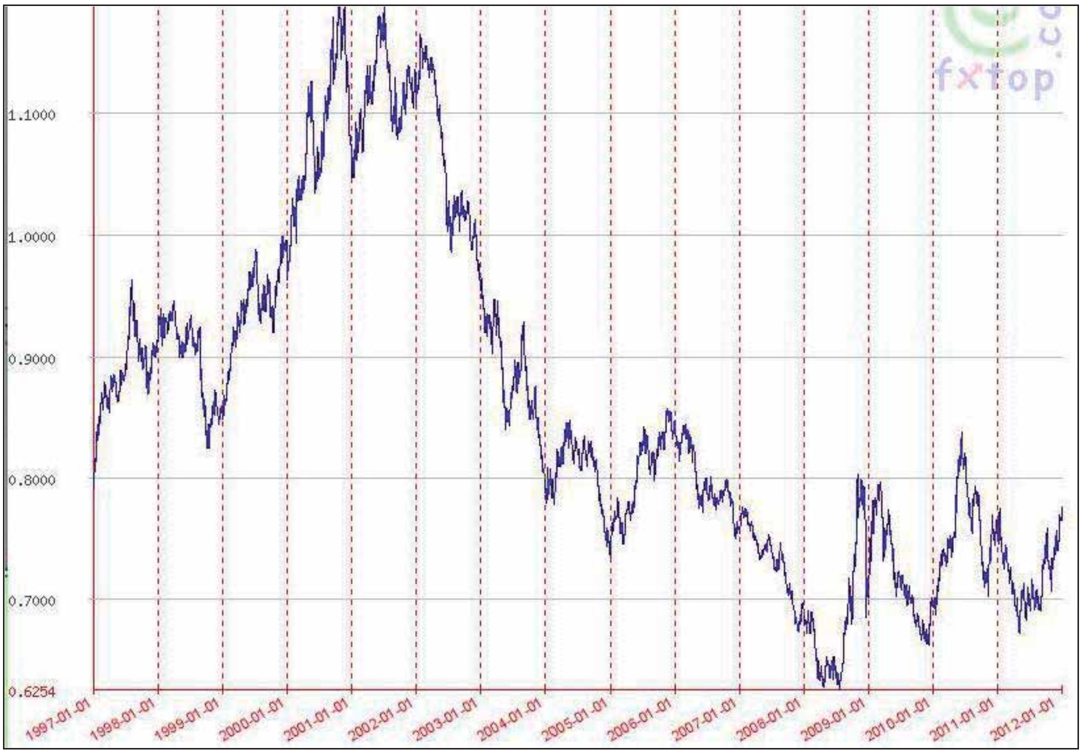

Figure 10.4. Exchange rate between USD and EUR from 1997-2012 (http://fxtop.com/)

CMDT (*Compagnie Malienne pour le Développement des Textiles*) created in 1974 and currently in the process of privatisation holds the monopoly of buying the cotton from farmers in Mali. The company has created its own spatial delimitation in zones and sectors. The zones and sectors are illustrated in Figure 10.5.

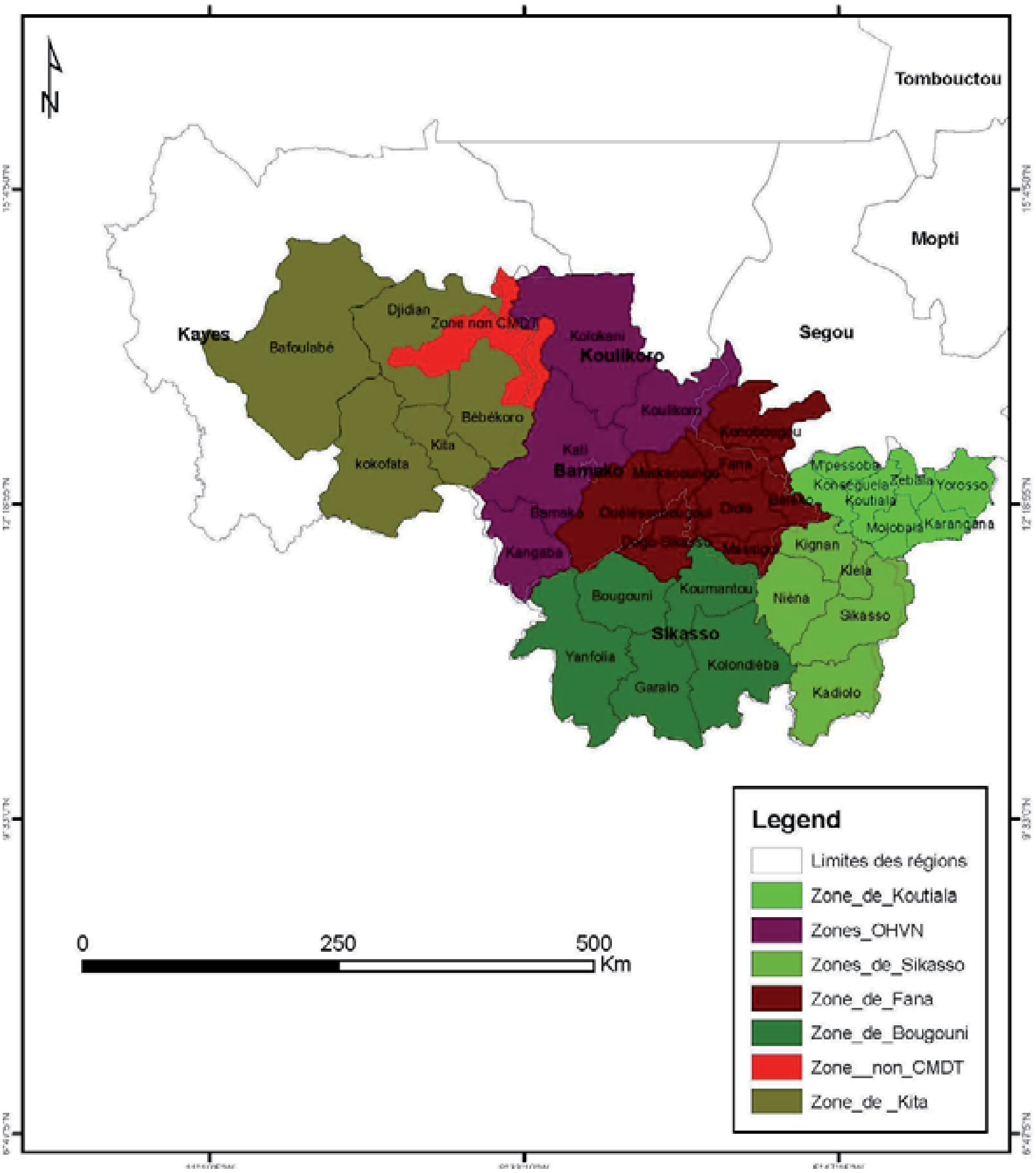

Figure 10.5. Zones and sectors as defined by CMDT

Annual production by CMDT zone is shown in Table 10.2 . More detailed statistical information such as production and cultivated area per sector is presented in Annexe B.

Table 10.2. Production of cotton (lint) from 2000 to 2008 by CMDT zone (tonnes/year)

CMDT zones	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
FANA	9 642	98 443	65 978	98 867	98 660	84 436	70 271	34 046	29 142
BOUGOUNI	19 186	95 016	77 531	100 273	116 110	114 235	90 858	60 752	32 884
SIKASSO	29 652	105 630	112 768	133 994	104 288	105 315	79 358	45 792	29 997
KOUTIALA	108 675	144 038	102 042	169 973	149 921	121 215	91 895	57 754	72 855
SAN	40 059	56 304	23 926	51 583	42 143	39 607	28 288	12 486	22 735
KITA	22 427	36 036	35 255	38 436	46 912	43 588	37 831	21 015	9000
T. CMDT	229 641	535 467	417 500	593 126	558 034	508 396	398 501	231 845	196 613
SOS KBK					169	140	61		
OHVN[6]	13 085	35 522	22 222	27 539	31 577	25 607	16 403	10 393	4 849
Total Mali	242 726	570 989	439 722	620 665	589 780	534 143	414 965	242 238	201 462

Table 10.2 and Figure 10.6 shows that Koutiala is the CDMT zone with the highest concentration of cotton production.

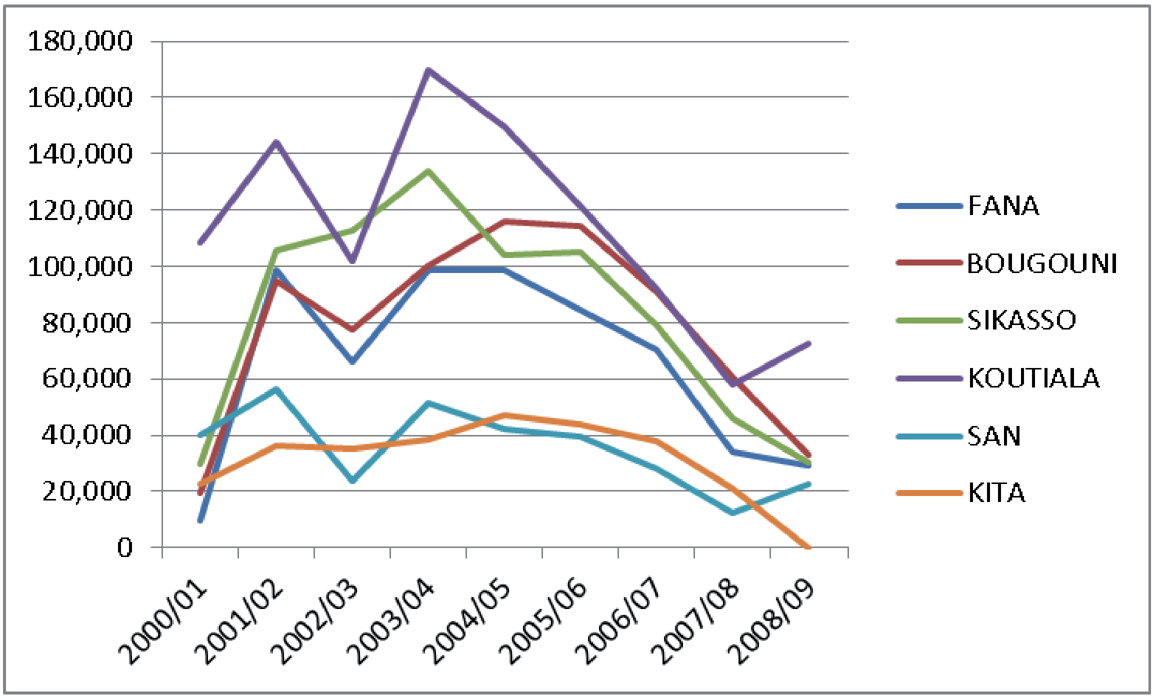

Figure 10.6. Production of cotton (lint) per CMDT sector (tonnes per year)

6 (OHVN) Office de la Haute Vallée du Niger)

Future use of cotton stalks for energy is therefore most likely in Koutiala and consequently Koutiala was chosen for the more detailed survey of existing use of cotton stalks in order to determine the sustainable potential of cotton stalks for energy. Detailed production statistics for the CDMT zone of Koutiala are presented in Table 10.3.

Table 10.3. Production of cotton from 2000 to 2008 in Koutiala by sector (tonnes/year)

CMDT sector	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Konséguéla		14 506	6 676	17 012	11 829	12 575	9 918	2 747	4 650
Koutiala	25 623	23 858	12 868	24 605	22 706	17 421	13 974	7 749	9 570
M'Pessoba	16 839	24 488	10 880	23 444	15 694	17 544	13 587	4 405	7 248
Molobala	15 643	22 381	20 379	29 030	27 068	20 526	13 118	6 491	7 216
Zébala	14 497	19 667	12 012	18 845	19 851	13 830	10 331	10 650	11 671
Karangana	21 379	21 495	23 887	32 504	32 557	21 458	16 890	13 626	17 028
Yorosso	14 694	17 643	15 340	24 533	20 216	17 861	14 077	12 086	15 472
KOUTIALA	108 675	144 038	102 042	169 973	149 921	121 215	91 895	57 754	72 855

10.2 Technical potential of cotton stalks for energy

The technical potential of cotton stalks for energy in Mali is estimated on the basis of the production of cotton (lint) presented in section 10.1 above and the estimated average residue-to-product ratio of 2.0 as determined in section 3.2.2. The production of cotton stalk (technical potential) in the years from 2000-2010 is shown in Table 10.4.

Table 10.4. Technical potential of cotton stalks from 2000-2010 (tonnes) per region

Year	Sikasso	Koulikoro	Segou	Kayes	Total
2000	316 238	46 108	78 584	44 614	485 544
2001	690 200	269 870	112 000	70 600	1 142 670
2002	584 682	176 400	47 852	70 510	879 444
2003	808 480	252 812	103 166	76 872	1 241 330
2004	740 638	260 474	84 286	94 162	1 179 560
2005	681 530	220 086	79 214	87 456	1 068 286
2006	524 222	161 192	68 732	75 784	829 930
2007	328 596	85 540	28 312	42 030	484 478
2008	269 630	57 396	47 666	30 700	405 392
2009	321 400	94 000	39 000	18 400	472 800
2010					522 000

Figure 10.7 shows the development in production of cotton stalk (technical potential) since 1984. It shows clearly that the region of Sikasso is the main cotton producing region. It also shows dramatic variation in production within a few years. These variations, which are mainly due to variation in world market prices having strong repercussions on farm-gate prices, are important to take into account when planning for using cotton stalks as an energy

resource. The dramatic fall in 2000 is due to a farmers' boycott as a result of discontent with CMDT about farmers' conditions. The regional distribution of cotton stalks illustrated in Figure 10.8 is based on information from Table 10.4.

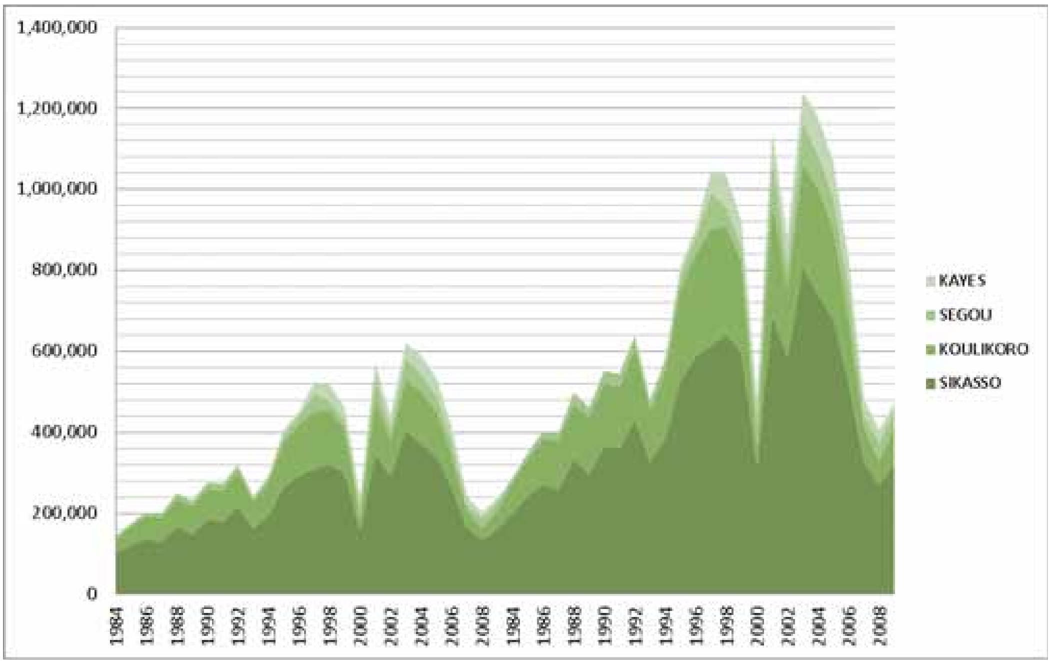

Figure 10.7. Technical potential of cotton stalks per region in the period from 1984 to 2009 (tonnes per year)

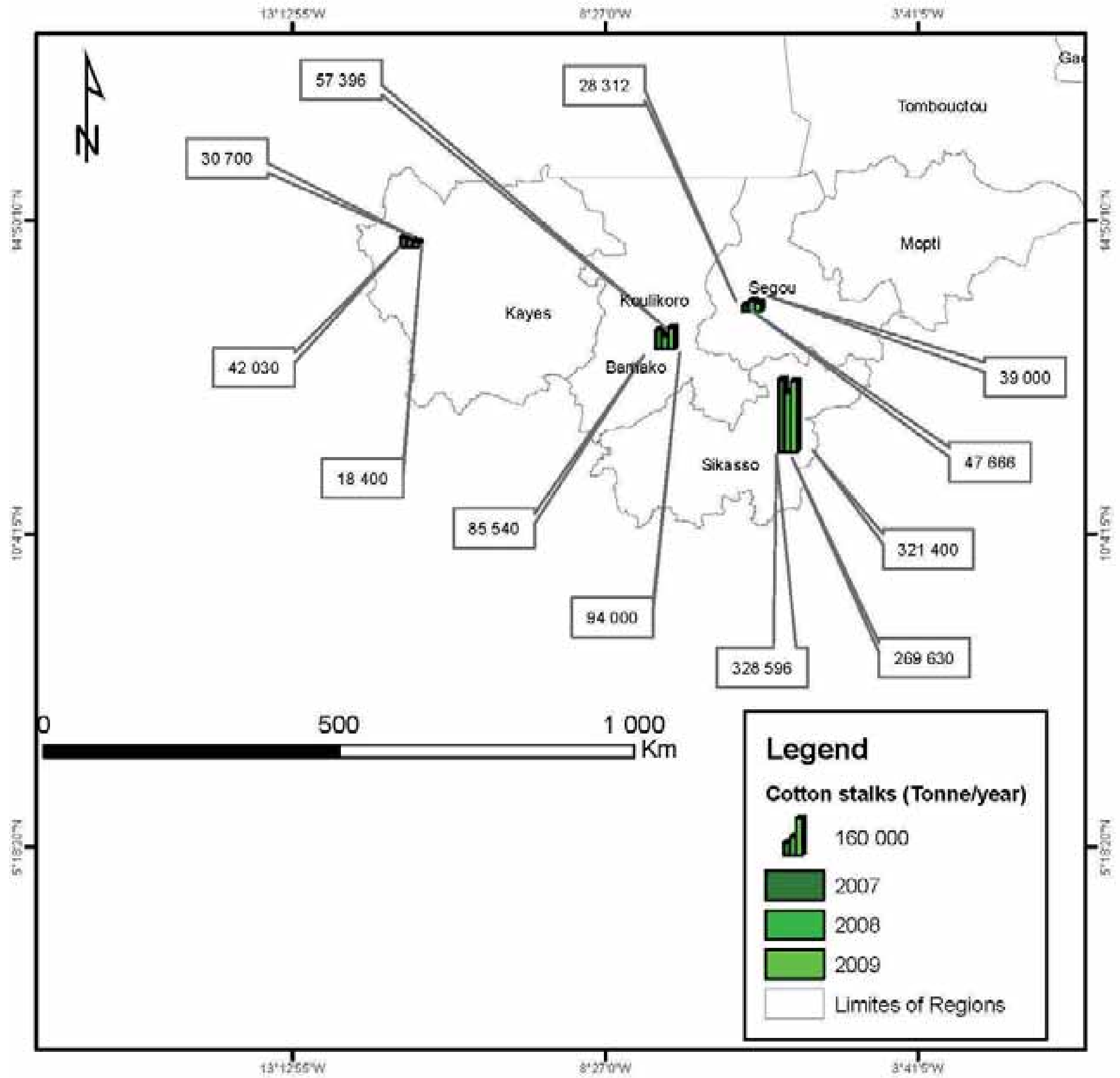

Figure 10.8. Technical potential of cotton stalks per region in the years 2007-2009

The technical potential of cotton stalks in the CMDT zones in the years from 2000 to 2008 is shown in Table 10.5

Table 10.5. Production of cotton stalks from 2000 to 2008 in CMDT zones (tonnes/year)

CMDT zone	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
FANA	19 284	196 886	131 956	197 734	197 320	168 872	140 542	68 092	58 284
BOUGOUNI	38 372	190 032	155 062	200 546	232 220	228 470	181 716	121 504	65 768
SIKASSO	59 304	211 260	225 536	267 988	208 576	210 630	158 716	91 584	59 994
KOUTIALA	217 350	288 076	204 084	339 946	299 842	242 430	183 790	115 508	145 710
SAN	80 118	112 608	47 852	103 166	84 286	79 214	56 576	24 972	45 470
KITA	44 854	72 072	70 510	76 872	93 824	87 176	75 662	42 030	18
T. CMDT	459 282	1 070 934	835 000	1 186 252	1 116 068	1 016 792	797 002	463 690	393 226
SOS KBK	0	0	0	0	338	280	122	0	0
OHVN	26 170	71 044	44 444	55 078	63 154	51 214	32 806	20 786	9 698
Total Mali	485 452	1 141 978	879 444	1 241 330	1 179 560	1 068 286	829 930	484 476	402 924

The technical potential of cotton stalks for sectors in the zone of Koutiala is shown in Table 10.6 and in Figure 10.9.

Table 10.6. Technical potential of cotton stalks from 2000 to 2008 in Koutiala by sector (tonnes/year)

CMDT sector	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Konséguéla	0	29 012	13 352	34 024	23 658	25 150	19 836	5 494	9 300
Koutiala	51 246	47 716	25 736	49 210	45 412	34 842	27 948	15 498	19 140
M'Pessoba	33 678	48 976	21 760	46 888	31 388	35 088	27 174	8 810	14 496
Molobala	31 286	44 762	40 758	58 060	54 136	41 052	26 236	12 982	14 432
Zébala	28 994	39 334	24 024	37 690	39 702	27 660	20 662	21 300	23 342
Karangana	42 758	42 990	47 774	65 008	65 114	42 916	33 780	27 252	34 056
Yorosso	29 388	35 286	30 680	49 066	40 432	35 722	28 154	24 172	30 944
KOUTIALA	217 350	288 076	204 084	339 946	299 842	242 430	183 790	115 508	145 710

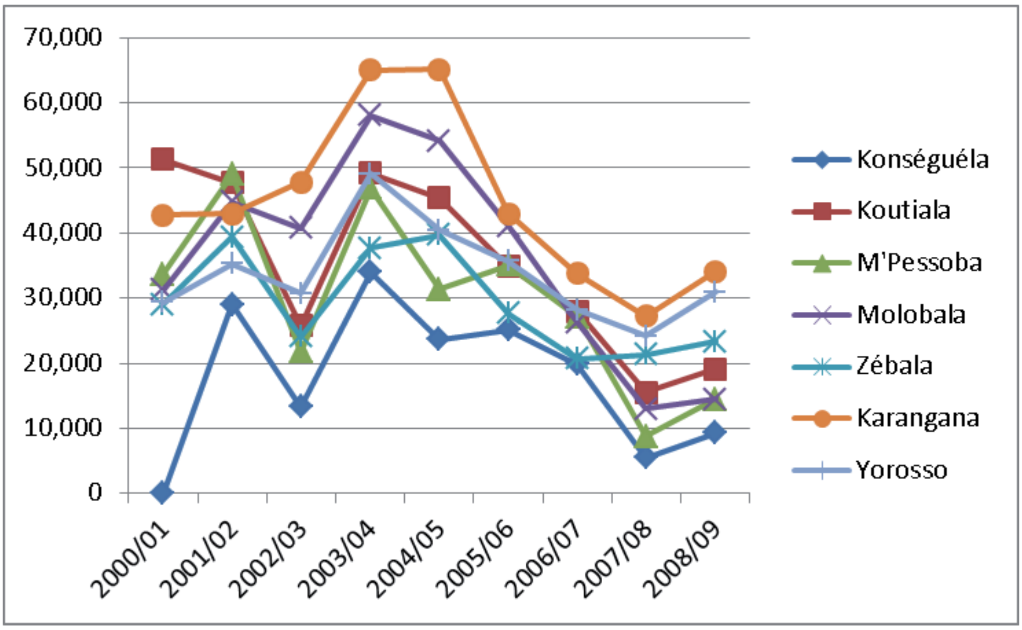

Figure 10.9. Technical potential of cotton stalks per sector in zone de Koutiala (1000 tonnes per year)

For details about the technical potential for sectors in other CMDT zones the reader is advised to consult detailed statistical data in Annexe B and to use the residue-to-product ratio defined in section 3.2.2.

Due to the large variability in production of cotton stalks over the last years the authors have found it impossible to make relevant forecasts for the future development of cotton stalks.

11 Sustainable potential of cotton stalks for energy in the zone of Koutiala

This chapter describes the sustainable potential of cotton stalks for energy in the CMDT zone of Koutiala. The sustainable potential is assessed on the basis of a field survey carried out in all sectors in Koutiala in 2010. The sustainable potential in this context is defined as the share of the cotton stalks which are currently burned.

11.1 Current use of cotton stalks

For many years, cotton stalks were burned in the fields to ease the cultivation of the next crop and to reduce the risk of residue-borne diseases. Extension services have advised against such burning for many years in order to reduce the risk of bushfires, to reduce air pollution and to encourage the farmers to recycle the organic matter into the soil. Part of the stalks is still burned, but the main part is currently used for purposes such as:

Bedding in corrals for the cattle
Cattle are held in corrals during night. They leave their manure in the corral, which is collected by the farmers and spread in nearby fields as fertilizer. The extension service has advised the farmers to collect the cotton stalks and use it for bedding in the corrals in order to increase the organic matter in the fertilizer.

Compost
Various composting techniques including a mixture with manure is practiced in order to provide organic fertilizer to the fields.

Soil protection
Part of the stalks is directly incorporated into the soil in order to improve organic matter in the soil.

Measure against soil erosion (fascines)
Cotton stalks are used to create barriers following the contour lines of the fields in order to capture water and protect against water erosion.

Fertilizer (potassium)
Cotton stalks are collected and burned in order to collect the ash which has high potassium content. The ash is later distributed as fertilizer.

There are no existing assessments of the use of cotton stalks available in Mali. A survey covering 100 farmers has therefore been conducted in order to make a first estimate of the current use of cotton stalks. The result of the survey is presented in Table 11.1. The percentage for each sector is based on a weighted average taking into consideration the production of each farmer.

Table 11.1. Current use of cotton stalk in the zone of Koutiala based on survey

CMDT Sector	Inter-views	Bedding	Compost	Burned	Incorporated into soil	Fascine	Potas-sium	Total
Konségula	10	27%	61%	2%	5%	0%	4%	100%
Koutiala	20	53%	28%	7%	7%	0%	5%	100%
M'Pessoba	10	17%	11%	59%	0%	0%	12%	100%
Molobala	15	62%	25%	0%	2%	1%	10%	100%
Zébala	10	19%	40%	33%	0%	0%	8%	100%
Karangana	25	41%	50%	0%	1%	4%	4%	100%
Yorosso	10	55%	37%	0%	1%	1%	6%	100%
KOUTIALA	100	41%	37%	12%	2%	1%	7%	100%

The table shows that, on average, about 12 % of the stalks is burned, 41 % is used for bedding, 37 % for compost, 7 % is burned for potassium, 2 % is incorporated into the soil and only 1 % is used to avoid soil erosion. No other uses were reported in the questionnaires.

The cotton stalks covered by the survey comprise 0.7 % of the total amount in the zone of Koutiala. The results should therefore be seen as mainly indicative.

The important variations in the figures from one sector to another may to a large extent be caused by the low number of questionnaires in each sector. However, as in the case of the similar survey on straw use in section 7.2.2 there is a risk of bias here related to factors such as:

- Representativeness of interviewees
- Interviewees' understanding of the questions
- Interviewers' understanding and interpretation of the questionnaires
- Interviewer bias
- Strategic answers

Representativeness

The research aimed at a spatial stratification within the seven zones included in the field survey, which seems to have been achieved. No tests have been made for representativeness with respect to size of farm, income level, education level, organizational level or ethnicity, but no signs of such bias have been found.

Interviewees' understanding of the questions

It is a challenge to make illiterate farmers estimate the shares of their production of stalks used for 5 different purposes. Various participative appraisal techniques were proposed, such as giving the farmer 10 sticks or 10 marbles for illustrating the shares. It is unclear to what extent such techniques were used.

Interviewers' understanding and interpretation of the questionnaires

The interviewers were trained by the head of the training unit in CMDT, who again was instructed by the responsible at Mali Folkecenter. This training by trainers approach may have resulted in slightly different interpretation of the questionnaires.

Interviewer bias

To reduce interviewer bias due to different interpretation of the questionnaires, different pre-understanding of the subject matter and differences in interview practice, interviews were planned to be conducted by more than one interviewers per sector. As can be seen in Table 4.3, in four out of seven sectors all interviews for the sector were carried out by the same person. For the sectors Koutiala, Moloba and M'Pessoba, two or more interviewers were conducting the interviews.

It is, for example, remarkable that two out of three sectors, where the survey shows that there is no burning of cotton stalks, are covered by only one interviewer per sector. This could indicate a difference related to the interviewer rather than a difference in practice. On the other hand, in the third sector with no burning, Molobala, the no-burning result is based on three different interviewers being responsible for the 15 interviews.

Strategic answers

In all cases representatives from CMDT conducted the interviews. This means that there is a risk that the respondent provides strategic answers to please the interviewer or to avoid any risk of negative sentiments. As in the case of the use of straw there may be a risk that farmers were reluctant to 'admit' that they are currently burning stalks, as this is not recommended by the extension service from CMDT. The high variations in the share which is burned (from 60 % and 33 % at the high end to zero in three zones) could be seen as a result of strategic answers.

Uncertainties on the shares burned in the field

As in the case of straw use, there may be a risk that the results presented in Table 11.1 underestimate the share of cotton stalks burned in the fields. This claim is based on the large variations in the results, in the fact that the survey does not control for interviewer bias, and because there is a high risk of strategic answers reflecting what the farmers expect the interviewer wants to hear.

11.2 Sustainable potential of cotton stalks for energy in the zone of Koutiala

For the purpose of this study, the sustainable potential of cotton stalks for energy is defined as the share which is currently burned. According to the survey about 12 % of the stalks are currently burned. Given that this figure is also representative for the other cotton producing zones, the sustainable potential for cotton stalks for energy will be around 48 000 tonnes at national level and 9 000 tonnes in the zone of Koutiala.

Given the results of the survey and the production of cotton stalks in 2008/09, the current use of stalks in the zone of Koutiala is shown in Table 11.2.

Table 11.2. Current use of technical potential of cotton stalks in 2008 based on survey results

CMDT Sector	Cotton stalks produced	Bedding	Compost	Burned	Incorpo-rated in soil	Fascine	Potassium
Konségula	4 650	1 269	2 857	105	232	0	187
Koutiala	9 570	5 051	2 665	700	708	-	445
M'Pessoba	7 248	1 250	795	4 308	-	-	895
Molobala	7 216	4 505	1 770	-	170	73	698
Zébala	11 671	2 269	4 652	3 831	-	-	919
Karangana	17 028	6 906	8 492	-	230	744	657
Yorosso	15 472	8 554	5 745	33	82	122	937
Koutiala	72 855	29 804	26 977	8 977	1 422	939	4 737

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Annexe A. Assessment of the environmental impact of using rice straw as a fuel, compared to incorporating the rice straw into the soil

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Literature review on the environmental impacts of incorporating rice residues into the soil

Incorporation of crop residues into the soil is a highly promoted agricultural management practice – especially in developing countries where access to external inputs such as chemical fertilizers is often limited. When crop residues are incorporated into the soil, some of the nutrients that were taken up by the crop are preserved in the system and the pool of soil organic carbon is maintained, which has a range of beneficial effects on the physical and chemical properties of the soil (Tiessen et al., 1994; Bruun et al., 2009). Therefore, incorporation of residues is normally assumed to have a positive effect on soil quality (Lal 2006; Lal 2008). However, in rice production systems, the practice has a negative side effect as harvest residues are a substantial source of CH_4 (Bossio et al., 1999, Liou et al., 2003; Knoblauch et al., 2011) which has about 23 times higher global warming potential than CO_2 in a time horizon of 100 years (IPCC, 2001). CH_4 is formed by the microbial breakdown of organic compounds under anaerobic conditions, at a very low redox potential, created by prolonged waterlogging, as commonly practiced in paddy rice cultivation (Reay et al., 2010; Smith et al., 2003). Reay, Smith *et al.* 2010; Smith, Ball *et al.* 2003CH_4 production in rice paddies largely depends on the readily decomposable organic materials which serve as a source of both carbon and energy to the microorganisms Wassmann and Aulakh 2000. Rice paddies have been identified as a major source of atmospheric CH_4 and the global annual CH_4 emission from paddy fields has been estimated to be about 54 CH_4 Tg year^{-1} (Reay et al., 2010). Estimated mean amounts of potential CH_4 emissions from Thai[7] rice fields range from 30-93 kg C ha^{-1} dependent on climatic zone and management system – the highest emissions are found under the warmest climatic conditions (Kimura et al., 2004).

Field studies of the effects of incorporating rice straw into the soil are rare and most studies of the subject have been carried out at experimental plots in Asia or as laboratory trials. No studies have been found to address the issue in an African context. However, several studies from Asia have reported marked increases in CH_4 emissions following incorporation of rice residues in flooded rice systems (Watanbe et al. 1995; Cai; 1997; Zou et al., 2005). The effects on CH_4 emissions are to a high degree dependent on the timing of the incorporation (Xu and Hosen, 2010). Accordingly, incorporation of rice straw early in the non-rice-growing season has been found to result in lower CH_4 emissions than incorporation right before rice cultivation – given that the fields are not flooded outside the cropping season (as it is the case in a Malian context) (Lu et al, 2000; Watanbe and Kimura, 1998). A laboratory study in which ^{13}C labelled rice straw was added to flooded pots found that the CH_4 evolution increased by 19, 97 and 228% with rice straw application at rates equivalent to 2, 4 and 6 tonne ha^{-1} respectively (Watanabe et al., 1998).

7 No studies from the African continent have been identified.

While the relationship between the content of soil organic carbon and soil quality is well documented for non-flooded soils (Weil et al 2003, Lal, 2004, Bruun et al., 2009; Bruun, 2010) the relation between these parameters in flooded rice soils has been less studied and due to the unique biochemical conditions under which paddy rice production takes place, the role of soil organic carbon for the sustainability of the system is unquestionably less important than in non flooded systems (Greenland 1997). However, some authors have attributed yield declines in rice production systems to declining contents of soil organic carbon (Grace et al., 2003; Lal, 2006) and it has been estimated that the productivity of African rice cultivation systems can be increased by 10-30 kg ha^{-1} yr^{-1} per if management practices that increase the soil organic carbon pool by 1 Mg ha^{-1} yr^{-1} are adopted (Lal, 2006). However, other authors have not found increases in content of soil organic matter to be associated with increases in the productivity of rice production systems (Duxbury, 2002).

With the purpose of investigating the relation between residue management and soil quality a field study was carried out in Macina in November 2010.

The field study

Methods – Management

The basic idea behind the field study was to simulate the effect of using rice straw as fuel instead of returning it to the soil by collecting soil samples from fields that did not receive any input of rice straw (as this was used for animal fodder or burned) with fields where rice straw had been incorporated into the soil.

Initially a group interview about agricultural management practice of the rice cultivation system in the area was carried out in order to get a general overview of the system.

Based on the results of the questionnaire survey (Table 1), farmers that had reported that they incorporated 75-100% of the rice straw into the soil and farmers that had answered that they did not return any rice straw to the soil were identified. The aim was to identify farmers from each category, interview them about their specific management practices and collect soil samples from their fields. It was, however only possible to find one out of the five farmers who had stated that they returned more that 50% of the rice straw to the field, as the remaining farmers were either absent or not known by the community. Instead it was decided to include some of the 13 farmers who had stated that they returned between 26 and 50% of the rice straw to the fields. However, when interviewed about their specific residue management practice it became clear that some farmers had understood the question from the questionnaire as ‘how large a proportion of the rice straw is left at the field when you harvest the rice’ (most of which is later eaten by the grazing cattle). Others had understood the question as it was intended to be understood, but it then turned out that the farmers did not spread the straw over the entire field before incorporating it, but instead the straw was incorporated in the area just around threshing area (equal to an area of 10-20 m^2).

	Burning	Incorporating	Fodder for own animals	Fodder for other animals	Other uses
0%	30	7	5	10	31
1-25%	15	20	5	26	13
26-50%	0	13	20	8	1
51-75%	0	2	12	0	0
76-100%	0	3	3	1	0

Table 1. Farmers' residue management (from questionnaire survey)

Findings - Management

The predominant management practice in Macina is to leave 35-45 cm of the rice straw on the field after harvest. This was confirmed by interviewing, observation and measurements as the area was visited during the harvest period. This part of the rice residue is grazed during the dry season so only about 10 cm of the residue is left when the fields are ploughed. The straw that is left after husking is normally used as fodder and the remaining part is normally burned or incorporated in the soil where the pile had been located - hence not spread over the entire field as the results of the questionnaires could indicate.

According to the interviews about the general management practices in the area, the farmers that return larger amounts of straw to the soil (>50%) are at the same time applying significant amounts of animal manure as a part of an on field composting system. This was confirmed by one of the farmers who had reported to return 100% of the straw to the soil (Kalifa Diarra). Kalifa Diarra has more than 100 head of cattle and about 30 ha of rice fields. Kalifa Diarra reported that he had enough manure to make compost for less than 2 ha. Kalifa Diarra represents one of the richest farmers in the community and his compost management system is clearly an exception from the common practices. Still it turned out – when interviewed in depth - that most of the straw was actually used for fodder and only a minor fraction was used for the compost (so in this case the 100% return reported in the questionnaire represents an over estimation of at least 50%).

Site Selection and Soil Sampling

Based on the new insights in the residue management practices and the fact that it was not possible to find one single farmer who returned rice straw to the whole field without adding compost at the same time it was decided to simulate the effects of sole addition of rice straw by comparing soil samples collected from the area where the pile of straw from the threshing is usually located to soil samples collected from the rest of the field. The location of these piles is (approximately) the same every year as there is an optimal place for the threshing machine to enter the field thus the pile will be located right next to this. It was also decided to include fields that received compost made from rice straw and cattle manure and from neighbouring fields that had not received compost. Before selecting the sampling plots a group interview about local soil types was carried out and based on the information from this it was decided to include fields at Bois Fing and Bois Bleau as these two soil types were the most widespread in the study area.

The local soil types

- Bois Fing: Black clayey soil that gets sticky and heavy when wet and very hard when dry. According to the interviewers this soil type is the best one for rice and the most widespread soil type in the area.
- Bois Bleau: Red clayey soil
- Tientien Fing: Dark sandy soil
- Bois Semo: Gravel

Bois Fing Bois Bleau

Soil samples were collected from the sites presented in Table 2

Plot	Farmer	Location (UTM 30 P)	Management	Soil Type
1[1] F_{Rem}	Jacob Gonno	211347 E 1537414 N	All straw removed	Bois Fing
2 F_{Rem}	Mamadou Camera	210579 E 1535888 N	All straw removed	Bois Fing
2 F_{Pile}	Mamadou Camera	210844 E 1535806 N	Under pile of straw from threshing	Bois Fing
3 F_{Rem}	Boufoine Tangara	210823 E 1537586 N	All straw removed	Bois Fing
3 F_{Pile}	Boufoine Tangara	210823 E 1537584 N	Under pile of straw from threshing	Bois Fing
4 B_{Rem}	Kaliffa Diarra	210534 E 1535488 N	All straw removed	Bois Bleau
4 B_{Straw_Man}	Kaliffa Diarra	210566 E 1535514 N	Compost of straw and manure	Bois Bleau
4 B_{Straw_Man}	Kaliffa Diarra	210517 E 1535488 N	Compost of straw and manure	Bois Bleau

Table 2. Soil sampling sites. [1] Soil from this field was sampled before it became evident that it was not possible to find a field that had received large amounts of rice straws to compare it with.

Volume specific soil samples were collected from the top soil using a soil core. Soil was sampled from the upper 15 cm of the soil in 3 replicates per field.

Figure 1. Soil sampling

Soil Analyses

Soil samples were air dried and transported to Denmark to be analysed at the soil laboratory at Department of Agriculture and Ecology, University of Copenhagen. Samples were dried at 80° Contents of Soil Organic Carbon and Total Nitrogen were determined by Isotope Ratio Mass Spectronomy using a continuous flow isotope ratio mass spectrometer. pH was determined in a 1:2.5 soil:water solution. As a previous study from the Niono area has suggested that the rice cultivation system is mining the soil for K (Defoer, 2000) it was decided to also include a screening for levels of exchangeable K using a soil test kit.

Findings Soil Sampling

	SOC (%)		N (%)	N SD	C:N	pH		K	Density g/cm^3
Boi Fing									
1 F_{Rem}	1.45	± 0.14	0.09	± 0.00	15.8	6.4	± 0.17	Low	1.3
2 F_{Rem}	0.92	± 0.10	0.06	± 0.01	15.3	3.9	± 0.10	Low	1.1
2 F_{Pile}	1.13	± 0.04	0.08	± 0.00	14.5	3.9	± 0.05	Low	1.2
3 F_{Rem}	1.00	± 0.20	0.07	± 0.01	13.9	4.8	± 0.34	Low	1.3
3 F_{Pile}	0.67	± 0.05	0.05	± 0.01	14.3	4.6	± 0.48	Low	1.5
Bois Bleau									
4 B_{Rem}	0.67^b	± 0.17	0.05^d	± 0.02	13.4	4.2	± 0.16	Low	1.6
4 B_{Straw_Man}	1.34^a	± 0.23	0.11^c	± 0.02	12.0	4.4	± 0.24	Medium	1.5
4 B_{Straw_Man}	1.36^a	± 0.13	0.11^c	± 0.01	12.3	4.5	± 0.33	Medium	1.3

Table 3: Results of the soil analyses (n=3).

No significant differences between contents of SOC and Total N were found in the samples from Bois Fing. For Bois Bleau the upper case letters indicate significant differences determined by pairwise t-tests (P<0.005) – Values with the same letter are not significantly different.

Contents of SOC and Total N were compared by pairwise t tests (2 F_{Rem}- 2 F_{Pile}, 3 F_{Rem}- 3 F_{Pile}, 4 B_{Rem} - 4 B_{Straw_Man}). No significant differences between samples collected from the areas where the piles had been located and the samples collected from the rest of the field were found. The content of SOC and Total N were significantly higher in the samples from areas that had received compost made from straw and manure and the K levels were also highest in these samples (no statistics for this parameter). The latter is, however, not representative for the common management in the area and clearly the amount of straw returned to the field in the compost system is dependent on the availability of significant amounts of animal manure, thus the soil quality of fields that are managed in this system does not represent the effects of incorporating rice straw into the soil but rather the effects of adding the manure. The low contents of exchangeable K in the soils managed under the common management regime is in line with the findings of Defoer (2000), but it must be kept in mind that the soil samples were collected just after the harvest which corresponds to the time of the year when the available nutrient reserves of the soil are lowest.

Conclusions

Based on this study the effect of using rice straw as fuel would not have severe implications for the soil quality in the study area as it is uncommon to return straw to the soil under the existing management system and as no differences between areas that have supposedly received larger quantities of rice straw than other areas can be documented.

As rice residues have traditionally been used in an interaction system between agriculturalists and pastoralists using the rice residues as fuel could be expected to create tension between the rice farmers and the herders who are dependent on the straw as fodder in the dry season. An investigation of the type of interactions between the herders and the rice farmers was not included in the study thus the contribution of manure from the livestock was not quantified and the nature of the interactions was not investigated further. Given the on-going conflicts over grazing areas in the Northern part of Mali, it is recommended that the interaction system in the study area is investigated further in order to assess the potential conflicts that could arise from using the rice straw as fuel.

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Annexe B. Statistical data on rice and cotton production in Mali

List of tables

Table 1. Production of rice (paddy) in tonnes per province in the period 1984-2011

Year	Segou	Mopti	Tom-bouctou	Sikasso	Gao	Kouli-koro	Kayes	Total
1984	87 682	4 654	1 687	10 599	2 228	1 403	1 101	109 354
1985	109 532	54 825	9 766	7 672	28 349	3 681	16	213 841
1986	114 311	53 812	21 504	25 275	8 685	1 455	96	225 138
1987	124 982	66 232	9 752	15 957	16 760	2 692	193	236 568
1988	155 072	70 578	27 852	8 639	25 610	46	0	287 797
1989	160 014	91 639	27 035	24 539	32 172	2 350	0	337 749
1990	153 534	56 272	38 592	13 225	11 911	8 301	531	282 366
1991	219 966	81 953	51 568	54 102	15 753	22 472	8 535	454 349
1992	218 645	67 882	43 317	50 223	13 232	14 548	2 171	410 018
1993	238 752	63 687	35 925	57 604	11 004	18 016	2 621	427 609
1994	234 390	102 706	42 159	61 324	7 680	17 431	3 437	469 127
1995	283 069	67 865	28 589	65 855	6 875	19 991	3 846	476 090
1996	339 780	109 401	58 631	76 244	9 451	30 418	3 480	627 405
1997	348 841	46 174	38 682	87 289	17 752	35 952	1 055	575 745
1998	389 784	134 461	46 951	91 408	17 020	37 638	594	717 856
1999	396 902	88 271	78 702	119 194	15 834	25 599	2 638	727 140
2000	429 094	108 398	52 976	92 796	31 306	26 801	1 437	742 808
2001	467 949	205 733	99 613	89 054	35 901	35 793	6 895	940 938
2002	438 610	68 228	67 662	74 094	23 646	17 741	3 222	693 203
2003	515 461	189 491	74 607	103 077	29 866	24 691	1 024	938 217
2004	429 153	114 358	44 231	81 288	25 196	20 141	3 719	718 086
2005	513 297	117 744	103 735	118 157	42 313	48 817	1 761	945 824
2006	520 818	195 632	134 444	124 745	48 645	21 066	7 887	1053 237
2007	515 560	247 722	121 403	127 605	34 839	31 669	3 585	1082 383
2008	843 924	366 267	161 975	158 514	42 528	48 133	2 905	1624 246
2009	774 800	369 010	227 700	268 300	83 630	72 930	57 700	1854 070
2010	946 320	439 472	322 925	191 941	65 328	133 557	94 519	2194 062
2011	801 087	278 356	362 175	97 185	39 562	160 506	2 601	1741 472

Source: FAO statistics 2012 www.countrystat.org

Note: This is based on local statistics on the website. According to national statistics on the website, production in 2009 and 2010 is 1,950,805 and 2,305,612 tonnes respectively

Table 2. Cultivated area of rice (ha)

Year	Segou	Mopti	Tombouctou	Sikasso	Gao	Koulikoro	Kayes	Total
2001	123 619	182 532	32 042	68 191	33 420	23 984	4 451	468 239
2002	114 970	107 648	27 571	63 348	26 188	12 996	3 890	356 611
2003	123 626	154 862	23 497	60 904	21 176	20 818	758	405 641
2004	112 341	119 626	22 349	19 418	22 013	16 675	2 493	314 915
2005	104 097	156 818	36 258	59 321	29 056	26 494	1 979	414 023
2006	108 171	130 245	42 244	66 096	44 778	10 741	6 219	408 494
2007	116 482	140 186	39 108	53 180	28 785	12 134	1 995	391 870
2008	146 850	189 048	38 236	60 120	27 262	18 223	2 813	482 552
2009	149 730	251 530	45 230	102 490	46 180	28 080	36 640	659 880
2010	128 976	137 949	34 180	59 682	42 444	31 400	37 246	471 877
2011	293 057	215 429	95 842	67 611	87 826	67 276	3 367	830 408

Source: FAO statistics 2012 *www.countrystat.org*

Note: This is based on local statistics on the website. According to national statistics on the website, cultivated area in 2009 and 2010 is 845,552 and 686,496 hectares respectively

Table 3 Calculated yield (tonnes/ha)

Year	Segou	Mopti	Tombouctou	Sikasso	Gao	Koulikoro	Kayes	Total
2001	3.79	1.13	3.11	1.31	1.07	1.49	1.55	2.01
2002	3.81	0.63	2.45	1.17	0.90	1.37	0.83	1.94
2003	4.17	1.22	3.18	1.69	1.41	1.19	1.35	2.31
2004	3.82	0.96	1.98	4.19	1.14	1.21	1.49	2.28
2005	4.93	0.75	2.86	1.99	1.46	1.84	0.89	2.28
2006	4.81	1.50	3.18	1.89	1.09	1.96	1.27	2.58
2007	4.43	1.77	3.10	2.40	1.21	2.61	1.80	2.76
2008	5.75	1.94	4.24	2.64	1.56	2.64	1.03	3.37
2009	5.17	1.47	5.03	2.62	1.81	2.60	1.57	2.81
2010	7.34	3.19	9.45	3.22	1.54	4.25	2.54	4.65
2011	2.73	1.29	3.78	1.44	0.45	2.39	0.77	2.10

Source: FAO statistics 2012 *www.countrystat.org*

Note: This is based on local statistics on the website. If yield is calculated based on national statistics on the website yield in 2009 and 2010 is 2.31 and 3.36 tonnes/hectare respectively

Table 4. Rice production in Office Riz Segou for the period of 2004 to 2008

Campagne	Dioro	Sansanding	Tamani	Total
		Production (tonnes)		
2004/2005	22 172	3 456	510	26 138
2005/2006	25 076	8 756	10 405	44 237
2006/2007	21 720	5 921	4 903	32 544
2007/2008	18 508	9 224	2 425	30 157
2008/2009	25 945	18 792	15 951	60 688
Average	22 684	9 230	6 839	38 753
		Cultivated area (hectare)		
2004/2005	11 670	2 160	319	14 149
2005/2006	11 306	4 761	6 264	22 331
2006/2007	12 189	4 137	5 255	21 581
2007/2008	10 730	6 117	3 520	20 367
2008/2009	13 065	9 448	8 324	30 837
Average	11 792	5 324	4 736	21 853
		Yield (tonnes/ha)		
2004/2005	1.90	1.60	1.60	1.85
2005/2006	2.22	1.84	1.66	1.98
2006/2007	1.78	1.43	0.93	1.51
2007/2008	1.72	1.51	0.69	1.48
2008/2009	1.99	1.99	1.92	1.97
Average	1.92	1.73	1.44	1.77

Source : Annual reports for respective years Office Riz Segou

Table 5. Rice production in Office Riz Mopti for the period of 2004 to 2008

Campagne	Mopti-Nord	Mopti-Sud	Sofara	Diaka	Outside scheme	Total
			Production (tonnes)			
2006/2007	4 323	7 238	432	1 878	1 578	15 449
2007/2008	7 434	8 458	1 494	1 638	2 561	21 585
2008/2009	14 104	17 807	2 627	2 899	2 626	40 063
Average	8 620	11 168	1 518	2 138	2 255	25 699
			Cultivated area (hectare)			
2006/2007	3 555	5 952	355	1 544	1 298	12 704
2007/2008	5 037	5 730	1 012	1 110	1 735	14 624
2008/2009	6 993	8 828	1 302	1 437	1 302	19 862
Average	5 195	6 837	890	1 364	1 445	15 730
			Yield (tonnes/ha)			
2006/2007	1.22	1.22	1.22	1.22	1.22	1.22
2007/2008	1.48	1.48	1.48	1.48	1.48	1.48
2008/2009	2.02	2.02	2.02	2.02	2.02	2.02
Average	1.66	1.63	1.71	1.57	1.56	1.63

Source : *Annual reports for respective years Office Riz Mopti*

Table 6. Production of cotton (lint) from 1984-2009 (tonnes) per region

Year	Sikasso	Koulikoro	Segou	Kayes	Total
1984	100 581	36 934	6 746	..	144 261
1985	121 965	45 396	7 732	..	175 093
1986	135 787	56 524	9 342	..	201 653
1987	128 502	60 873	9 512	..	198 887
1988	166 826	68 150	14 080	..	249 056
1989	147 638	71 122	12 035	..	230 795
1990	183 538	77 114	15 371	..	276 023
1991	179 646	76 812	15 972	..	272 430
1992	216 309	88 287	14 735	93	319 424
1993	163 514	64 665	11 311	754	240 244
1994	193 798	80 880	15 328	3 015	293 021
1995	264 795	111 653	17 893	11 598	405 939
1996	293 260	126 035	21 053	11 685	452 033
1997	308 358	143 526	43 982	27 037	522 903
1998	321 105	132 866	24 056	40 388	518 415
1999	298 594	110 241	18 568	32 389	459 792
2000	158 119	23 054	39 292	22 307	242 772
2001	345 100	134 935	56 000	35 300	571 335
2002	292 341	88 200	23 926	35 255	439 722
2003	404 240	126 406	51 583	38 436	620 665
2004	370 319	130 237	42 143	47 081	589 780
2005	340 765	110 043	39 607	43 728	534 143
2006	262 111	80 596	34 366	37 892	414 965
2007	164 298	42 770	14 156	21 015	242 239
2008	134 815	28 698	23 833	15 350	202 696
2009	160 700	47 000	19 500	9 200	236 400
2010					261 000

Source: FAO statistics 2012 www.countrystat.org

Table 7. Cultivated area (ha) from 2001 to 2009 per region

Year	Sikasso	Koulikoro	Segou	Kayes	Total
2001	345 100	134 935	56 000	35 300	571 335
2002	292 341	88 200	23 926	35 255	439 722
2003	404 240	126 406	51 583	38 436	620 665
2004	370 319	130 237	42 143	47 081	589 780
2005	340 765	110 043	39 607	43 728	534 143
2006	262 111	80 596	34 366	37 892	414 965
2007	164 298	42 770	14 156	21 015	242 239
2008	134 815	28 698	23 833	15 350	202 696
2009	160 700	47 000	19 500	9 200	236 400

Source: FAO statistics 2012 www.countrystat.org

Table 8. Calculated average yield (tonnes/ha) from 2001 to 2009 per region

Year	Sikasso	Koulikoro	Segou	Kayes	Total
2001	1.11	0.96	1.21	1.03	1.07
2002	1.07	0.84	0.64	1.08	0.98
2003	1.21	0.99	1.15	0.90	1.13
2004	1.09	0.96	0.96	0.99	1.04
2005	2.71	0.32	0.92	1.12	0.97
2006	0.87	0.83	0.78	0.98	0.86
2007	0.89	0.79	0.88	0.70	0.85
2008	1.05	0.93	0.99	1.00	1.02
2009	1.03	0.90	0.80	0.70	0.96

Source: FAO statistics 2012 www.countrystat.org

Table 9. Cotton production (tonnes/year) in the period from 1984 to 2008

Campagne	Kayes	Bamako	Fana	Bougouni	Sikasso	Koutiala	San	Segou	Kita	Total CMDT	SOS KBK	OHVN	Total Mali
84/85			31 740	9 054	35 468	51 181	11 624		0	139 067		5 194	144 261
85/86			39 861	13 419	43 436	60 626	12 215		0	169 557		5 535	175 092
86/87			49 634	13 735	46 170	72 332	12 892		0	194 763		6 890	201 653
87/88			51 582	19 393	46 729	57 545	14 347		0	189 596		9 291	198 887
88/89			58 245	25 589	56 309	76 983	22 025		0	239 151		9 905	249 056
89/90			59 852	27 119	49 728	64 332	18 494		0	219 525		11 270	230 795
90/91			65 232	32 332	60 430	81 337	24 811		0	264 142		11 881	276 023
91/92			65 474	34 510	60 528	74 272	26 308		0	261 092		11 338	272 430
92/93			76 190	43 108	67 042	93 577	27 317		0	307 234	93	12 097	319 424
93/94			54 514	32 806	51 506	71 107	19 406		0	229 339	754	10 151	240 244
94/95			68 040	37 741	59 779	84 606	27 000		0	277 166	3 015	12 840	293 021
95/96			95 801	52 674	81 651	117 865	30 497		11 598	390 088		15 851	405 939
96/97			104 077	62 634	94 781	120 544	36 352		11 684	430 074		21 958	452 032
97/98			114 599	74 541	108 610	125 207	43 982		27 037	493 976		28 927	522 903
98/99			97 456	88 920	92 484	122 638	41 425		40 757	483 680		34 684	518 364
99/2000			80 570	85 873	91 201	100 612	39 366		32 367	429 989		29 134	459 123
2000/01			9 642	19 186	29 652	108 675	40 059		22 427	229 641		13 085	242 726
2001/02			98 443	95 016	105 630	144 038	56 304		36 036	535 467		35 522	570 989
2002/03			65 978	77 531	112 768	102 042	23 926		35 255	417 500		22 222	439 722
2003/04			98 867	100 273	133 994	169 973	51 583		38 436	593 126		27 539	620 665
2004/05			98 660	116 110	104 288	149 921	42 143		46 912	558 034	169	31 577	589 780
2005/06			84 436	114 235	105 315	121 215	39 607		43 588	508 396	140	25 607	534 143
2006/07			70 271	90 858	79 358	91 895	28 288		37 831	398 501	61	16 403	414 965
2007/08			34 046	60 752	45 792	57 754	12 486		21 015	231 845		10 393	242 238
2008/09			29 142	32 884	29 997	72 855	22 735		9 000	196 613		4 849	201 462

Source: CMDT. Campagne 2008/09 is referred to as 2008 in the regional statistics

Table 10. Area cultivated (ha) by cotton (sown) in the period from 1984 to 2008

Campagne	Kayes	Bamako	Fana	Bougouni	Sikasso	Koutiala	San	SEGOU	KITA	Total CMDT	SOS KBK	OHVN	Total Mali
84/85			25 193	6 209	24 164	45 382	12 250		0	113 198			113 198
85/86			32 329	10 142	29 646	53 079	14 022		0	139 18			139 218
86/87			35 297	10 546	32 580	55 705	11 619		0	145 747			145 747
87/88			35 012	14 537	32 089	47 140	13 444		0	142 222			142 222
88/89			42 641	19 493	35 976	61 867	20 159		0	180 136			180 136
89/90			42 179	23 207	39 690	55 046	18 213		0	178 335			178 335
90/91			44 972	25 731	43 370	58 719	21 631		0	194 423			194 423
91/92			48 215	28 313	45 670	59 955	22 607		0	204 760			204 760
92/93			58 523	31 907	49 388	69 277	25 176		0	234 271			234 271
93/94			47 724	28 303	40 870	55 967	18 880		0	191 744			191 744
94/95			63 455	36 032	54 512	77 842	23 279		0	255 120		13 318	268 438
95/96			80 155	44 246	63 174	93 387	26 760		13 897	321 619		17 446	339 065
96/97			102 264	56 977	78 147	110 582	36 551		12 680	397 201		23 198	420 399
97/98			111 138	67 226	90 978	131 877	44 625		21 056	466 900		30 750	497 650
98/99			95 258	75 283	88 194	124 055	43 991		41 800	468 581			468 581
99/2000			95 991	87 628	86 326	98 401	33 824		40 326	442 496		39 803	482 299
2000/01			10 922	18 553	23 243	100 153	34 395		24 458	211 724		16 184	227 908
2001/02			100 312	89 117	90 368	131 526	46 208		34 378	491 909		40 254	532 163
2002/03			76 343	78 987	81 964	113 038	37 189		32 522	420 043		29 250	449 293
2003/04			94 400	94 943	101 629	137 502	44 688		42 781	515 943		32 952	548 895
2004/05			103 268	95 535	105 517	137 345	43 821		47 525	533 011	212	31 748	564 971
2005/06			96 468	97 901	105 144	139 417	43 220		38 546	520 696	333	29 503	550 532
2006/07			83 536	95 666	84 777	120 705	35 758		38 619	459 061	204	21 209	480 474
2007/08			41 649	72 802	50 167	61 109	13 543		29 698	268 968	177	14 782	283 927
2008/09			32 802	32 272	26 604	63 823	19 909		14 274	189 684		7 028	196 712

Source: CMDT. Campagne 2008/09 is referred to as 2008 in the regional statistics

Table 11. Production of cotton from 2000 to 2008 by CMDT zone and sector

CMDT sector	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Béléko	1 029	23 423	13 597	24 862	17 741	19 433	16 102	6 279	8 674
Dioïla	1 438	29 038	22 683	29 206	31 388	27 620	25 034	13 880	8 555
Fana		11 912	8 432	13 639	15 073	12 121	9 532	4 762	1 597
Markacoungo	3 943	13 079	8 005	9 929	11 678	8 144	5 562	2 549	3 437
Massigui	588	10 817	8 467	12 007	12 348	9 605	7 963	4 907	2 935
Konobougou	2 644	10 174	4 794	9 224	10 432	7 513	6 078	1 669	3 944
FANA	9 642	98 443	65 978	98 867	98 660	84 436	70 271	34 046	29 142
Bougouni	3 300	17 370	13 689	16 645	19 392	19 651	15 354	10 216	5 150
Dogo	585	8 744	5 622	8 280	10 140	9 676	8 587	6 117	2 606
Garalo	3 397	10 042	9 505	12 175	19 255	17 645	15 037	9 689	7 389
Koumantou	1 552	17 544	14 903	19 620	20 031	18 619	13 876	9 849	5 651
Kolondiéba	5 726	25 338	22 796	30 147	29 459	30 195	24 897	17 112	7 708
Yanfolila	4 626	15 978	11 016	13 406	17 833	18 449	13 107	7 769	4 380
BOUGOUNI	19 186	95 016	77 531	100 273	116 110	114 235	90 858	60 752	32 884
Kignan	604	24 829	19 877	31 016	25 347	23 563	17 070	8 098	6 401
Kléla	3 840	18 071	18 652	22 803	17 192	15 381	13 864	9 864	7 934
Niéna	45	23 494	21 786	27 125	20 697	22 045	15 921	6 709	2 033
Sikasso	6 434	19 860	20 746	23 489	17 475	19 374	13 826	8 612	4 101
Kadiolo	18 729	19 376	31 707	29 561	23 577	24 952	18 677	12 509	9 528
SIKASSO	29 652	105 630	112 768	133 994	104 288	105 315	79 358	45 792	29 997
Konséguéla		14 506	6 676	17 012	11 829	12 575	9 918	2 747	4 650
Koutiala	25 623	23 858	12 868	24 605	22 706	17 421	13 974	7 749	9 570
M'Pessoba	16 839	24 488	10 880	23 444	15 694	17 544	13 587	4 405	7 248
Molobala	15 643	22 381	20 379	29 030	27 068	20 526	13 118	6 491	7 216
Zébala	14 497	19 667	12 012	18 845	19 851	13 830	10 331	10 650	11 671
Karangana	21 379	21 495	23 887	32 504	32 557	21 458	16 890	13 626	17 028
Yorosso	14 694	17 643	15 340	24 533	20 216	17 861	14 077	12 086	15 472
KOUTIALA	108 675	144 038	102 042	169 973	149 921	121 215	91 895	57 754	72 855
Kimparana	10 482	17 619	9 671	16 342	15 175	12 289	9 771	6 293	6 802
San	1 828								
Bla	19 922	23 853	9 199	20 816	14 454	13 717	11 198	2 491	8 520
Yangasso	5 785	11 611	3 757	11 202	9 375	10 853	5 881	3 364	6 924
Tominian	2 042	3 221	1 299	3 223	3 139	2 748	1 438	338	489
SAN	40 059	56 304	23 926	51 583	42 143	39 607	28 288	12 486	22 735
SEGOU									
Djidjan	3 106	5 486	5 275	6 936	7 031	6 316	5 352	2 457	1 433
Kita	4 032	6 545	5 927	7 737	11 049	9 426	8 445	4 671	1 502
Kokofata	10 483	15 743	14 634	12 654	14 441	13 509	12 226	7 684	3 064
Sébékoro	4 806	8 262	9 419	11 109	14 391	14 337	11 808	6 203	3 001
KITA	22 427	36 036	35 255	38 436	46 912	43 588	37 831	21 015	9 000
Total CMDT	229 641	535 467	417 500	593 126	558 034	508 396	398 501	231 845	196 613
SOS KBK					169	140	61		
OHVN	13 085	35 522	22 222	27 539	31 577	25 607	16 403	10 393	4 849
Total Mali	242 726	570 989	439 722	620 665	589 780	534 143	414 965	242 238	201 462

Source: CMDT

Table 12. Area cultivated (ha) by cotton (sown) in 2000 to 2008 by CMDT sectors and zones

CMDT sector	2000/01	2001/02	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09
Béléko	1 155	22 593	15 179	21 905	21 222	21 258	19 387	7 628	8 650
Dioïla	1 744	29 403	23 502	27 527	30 571	30 175	26 782	15 873	9 596
Fana		11 800	11 340	12 859	15 364	12 748	11 865	6 325	5 011
Markacoungo	4 625	14 969	8 829	10 965	12 567	11 241	8 188	4 223	2 675
Massigui	532	11 433	9 559	11 802	12 034	11 378	9 176	5 114	3 536
Konobougou	2 866	10 114	7 934	9 342	11 510	9 668	8 138	2 486	3 334
FANA	10 922	100 312	76 343	94 400	103 268	96 468	83 536	41 649	32 802
Bougouni	3 116	15 098	13 226	15 597	15 880	16 360	16 023	12 109	4 731
Dogo	646	8 204	7 281	8 145	8 177	7 977	7 978	6 292	2 402
Garalo	3 386	9 598	8 948	11 645	12 814	14 055	15 508	11 939	6 887
Koumantou	1 621	16 586	14 695	17 836	17 967	17 461	15 672	11 015	5 538
Kolondiéba	5 278	23 453	22 127	27 386	26 295	26 616	25 819	20 303	7 627
Yanfolila	4 506	16 178	12 710	14 334	14 402	15 432	14 666	11 144	5 087
BOUGOUNI	18 553	89 117	78 987	94 943	95 535	97 901	95 666	72 802	32 272
Kignan	548	21 452	15 979	21 398	24 550	23 683	17 677	8 654	5 295
Kléla	2 458	13 297	12 831	15 583	16 368	15 809	12 195	9 252	6 544
Niéna	37	20 318	18 807	22 908	21 823	22 094	18 630	9 009	1 884
Sikasso	5 134	17 519	16 444	18 889	19 454	19 558	15 688	9 658	3 831
Kadiolo	15 066	17 782	17 903	22 851	23 322	24 000	20 587	13 594	9 050
SIKASSO	23 243	90 368	81 964	101 629	105 517	105 144	84 777	50 167	26 604
Konséguéla		13 691	9 843	14 429	13 286	13 733	12 049	3 460	4 190
Koutiala	25 402	21 478	16 552	21 484	21 365	21 588	18 216	7 711	8 441
M'Pessoba	14 816	21 842	15 999	20 158	18 074	18 506	15 040	5 692	6 885
Molobala	14 556	19 939	20 047	22 337	23 309	23 153	19 781	7 795	6 800
Zébala	13 746	16 333	15 320	17 017	16 608	16 773	14 380	8 796	9 778
Karangana	16 815	20 352	19 325	22 092	23 861	24 390	21 563	14 235	14 630
Yorosso	14 818	17 891	15 952	19 985	20 842	21 274	19 676	13 420	13 099
KOUTIALA	100 153	131 526	113 038	137 502	137 345	139 417	120 705	61 109	63 823
Kimparana	8 625	13 866	12 631	14 086	14 084	13 148	11 763	6 296	5 802
San	1 684								
Bla	16 809	19 404	15 437	18 167	17 667	17 191	13 781	3 557	8 180
Yangasso	5 093	9 211	6 759	9 230	9 070	9 051	7 352	3 134	5 405
Tominian	2 184	3 727	2 362	3 205	3 000	3 830	2 862	556	522
SAN	34 395	46 208	37 189	44 688	43 821	43 220	35 758	13 543	19 909
SEGOU									
Djidjan	3 618	4 946	5 292	6 845	8 039	5 691	5 458	3 342	2 300
Kita	5 163	7 454	5 742	9 511	11 150	8 877	9 488	7 260	2 667
Kokofata	10 704	14 814	13 813	15 156	14 567	12 107	11 896	9 612	4 655
Sébékoro	4 973	7 164	7 675	11 269	13 769	11 871	11 777	9 484	4 652
KITA	24 458	34 378	32 522	42 781	47 525	38 546	38 619	29 698	14 274
Total CMDT	211 724	491 909	420 043	515 943	533 011	520 696	459 061	268 968	189 684
SOS KBK					212	333	204	177	
OHVN	16 184	40 254	29 250	32 952	31 748	29 503	21 209	14 782	7 028
Total Mali	227 908	532 163	449 293	548 895	564 971	550 532	480 474	283 927	196 712

Source: CMDT