

Connecting poverty & ecosystem services

A series of seven country scoping studies

Focus on Mali



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Connecting poverty and ecosystem services: A series of seven country scoping studies

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Background

Ecosystems provide more than the resources needed for material welfare and livelihoods. In addition to supporting all life and regulating natural systems, they specifically provide health and cultural benefits to people. Moreover, their loss is a significant barrier to the achievement of the Millennium Development Goals related to reduction of poverty, hunger and disease. The Millennium Ecosystem Assessment (MA),¹ released in 2005, reported, though, that 15 of the 23 ecosystem services assessed were being degraded or used unsustainably.

In light of these findings, this report sets out to provide a preliminary overview of ecosystem services in Mali and the corresponding constituents and determinants of well-being related to the availability of these services. This paper is one of seven scoping studies prepared by the International Institute for Sustainable Development for the United Nations Environment Programme. Other countries examined in this series are Kenya, Mauritania, Mozambique, Rwanda, Tanzania and Uganda. All of the papers are available online at <http://www.iisd.org/economics/>

The objective of the series is not to provide a detailed assessment of the poverty-environment linkages, but to identify the regions within the countries where critical ecosystem services for human well-being are stressed, signalling the need for immediate attention. This information is expected to inform and guide the selection of potential areas where a more detailed local-scale integrated assessment of the links between ecosystem services and human well-being can be carried out.

These reports do not cover previous policy interventions, as the local-scale integrated assessment would gather such information and report on the impacts these policies have had in the past. Lessons learned can then be used together with new knowledge gathered on the links between ecosystem services and human well-being to design more finely-tuned intervention strategies that would seek to promote the reduction of poverty and improve well-being while protecting and enhancing vital ecosystem services.

¹ The Millennium Ecosystem Assessment was a four-year study requested by the United Nations Secretary General in 2001 to provide an overview of the state of the global ecosystems and the consequences of ecosystem changes on human well-being.

Executive Summary

1. The most highly stressed regions of Mali are the southern regions of Sikasso, Mopti and Segou. These are regions that particularly stand out, as they are endowed with many ecosystem services which are deteriorating, have high population densities and high levels of poverty.
2. There are many trade-offs that occur when using ecosystem services in an unsustainable manner—for example, while increased rice production has decreased child stunting, it has negatively impacted water quality and caused higher occurrences of floods.
3. Proper management of water, including appropriate technologies and policy mechanisms, will mitigate drought and ensure water availability.
4. The high population growth rate is another driver that will need to be addressed as it puts pressure on ecosystem services.

Ecosystem Services

The literature review of Mali’s ecosystem services revealed four critically stressed ecosystem services: maintenance of biodiversity; food and fibre provision; water supply, purification and regulation; and fuel provision.

Maintenance of biodiversity

Forests in Mali provide rich sources of biodiversity, but are also a source of food, fuel wood and medicine for Malians. However, biodiversity loss is occurring through a combination of factors including: climatic hazards such as drought; slash and burn agriculture; fuel wood consumption; bush fire; illegal hunting; expansion of agriculture; and population growth.

Ecosystem services and constituents of well-being: degrees of threat by region

	Mainten- ance of bio- diversity	Food prod- uction	Water supply	Energy resources	Ade- quately nour- ished	Clean water	Energy for warmth and cooking	Earn livi- hood	Incidence of poverty
Gao	X	X	X	O	X	X	X	X	78.7%
Kayes	X	X	X	X	X	X	O	X	62.4%
Kidal	O	O	X	O	X	X	X	X	92.8%
Koulikoro	X	X	X	X	X	X	O	X	59.5%
Mopti	X	X	X	O	X	X	O	X	76.2%
Segou	X	X	X	X	X	X	O	X	68.2%
Sikasso	X	X	X	X	X	X	X	X	65.8%
Tombouctou	X	X	X	O	X	X	X	X	76.8%

- X indicates an ecosystem service or well-being constituent under threat in the particular region
- O indicates that an ecosystem services or well-being constituent is not under threat
- **Bold** highlights those areas of immediate priority

Food and fibre provision

Agriculture in Mali is dominated by subsistence crops, yet various factors are undermining the ecosystem services that support agriculture such as persistent natural disasters such as drought, floods and locusts and irregular rain patterns. Desertification is also threatening one third of the country. Malians also rely on fish in the Niger River as a source of food and income, but fish production has steadily declined due to drought and water diversion.

Water supply, purification and regulation

Mali's main sources of surface water are the Niger and Senegal rivers. Due to uneven and irregular supply, less than half of the population has access to potable water, and agriculture accounts for 97 per cent of water withdrawals. Water quality is also a concern with increasing salinity, and chemical and biological contamination. Poor land management practices and deforestation have exacerbated natural limitations in water distribution and supply. Water quality is adversely affected by chemical agricultural inputs, irrigation practices and the poor regulation and disposal of waste.

Fuel provision

Traditional fuels such as wood and charcoal comprise 89 per cent of total energy use and 93 per cent of households use firewood for fuel. As a result, Mali's forests face extensive cutting for domestic energy along with other causes of deforestation such as heavy pressure from cropping, grazing and bush fires. A lack of community participation in natural resource management, technical strength in local government bodies and unfavourable centralized institutional structure and land tenure, contribute to the continuing rapid loss of forests.

Well-being

Human well-being is multi-dimensional with many constituents and is closely linked with the state of ecosystem services. This report focuses on those well-being determinants which are affected by the state of ecosystems services which include: ability to be adequately nourished; ability to access adequate clean water; ability to have energy and to keep warm and cook; and ability to earn a livelihood.

Ability to be adequately nourished

One of the main factors influencing poor nourishment is the inability to grow food, which in Mali is characterized by variable agricultural production, uneven water supply and desertification. As well, economic entitlements to buy food also underpin adequate nourishment, and rising grain prices due to drought and locust plagues have affected most of the population.

Ability to access adequate clean water

Water scarcity is not a primary issue in Mali, but only 49 per cent of the population has access to potable water. As well, 31 per cent of the population does not have access to improved sanitation. Poor land management practices have impacted on the watersheds' ability to provide an inexpensive method of purifying water and necessitating substantially higher future investments to have clean water.

Ability to have the energy to keep warm and cook

A reliable source of energy is required for daily activities like cooking and for warmth. The most important source of energy in Mali is wood and firewood consumption is expanding more rapidly than its market supply. Malians are even harvesting fruit trees which demonstrates an obvious shortage in adequate wood supplies.

Ability to earn a livelihood

Mali's economic entitlements are low—73 per cent of the population lives on less than \$1/day and 90 per cent live on less than \$2/day. The majority of Malians derive their livelihood from raising crops and livestock and selling surpluses in the market, but the number of cattle, because of increased desertification, is not expected to reach pre-drought levels and decreasing agriculture production will also negatively impact Malians' ability to earn income.

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Introduction

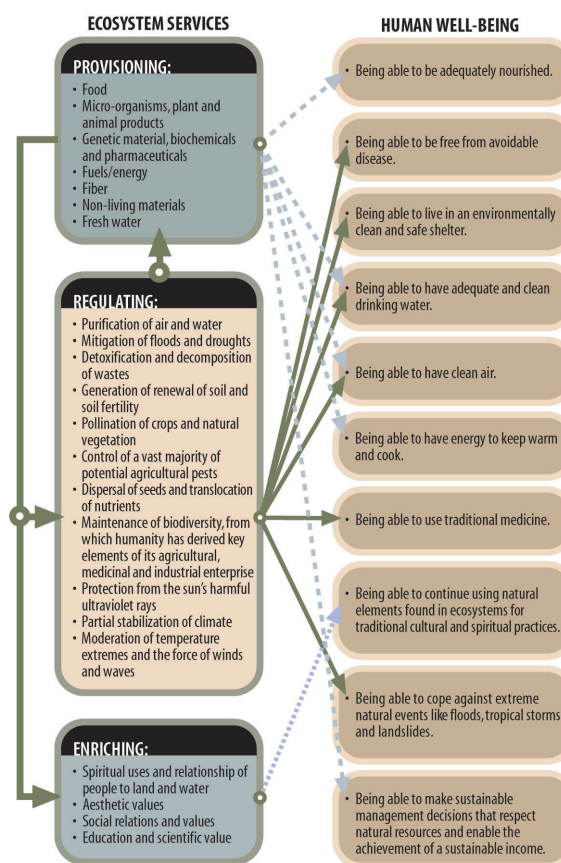
The primary objective of this report is to identify regions within Mali where critical ecosystem services for human well-being are stressed. These regions were identified through an extensive literature review and research which spatially connected ecosystem services and human well-being within Mali. The framework of ecosystem services and human well-being categories developed by the Millennium Ecosystem Assessment, illustrated in Figure 1, was used (Alcamo *et al.* 2003; Duraiappah 2002; Daily 1997). This review does not intend to be an exhaustive description of all ecosystem services. Instead it identifies those ecosystem services in Mali found to be deteriorating or in danger of deteriorating in the near future—in other words, ecosystem services that are stressed. Furthermore, when considering human well-being, we broaden our attention beyond the traditional constituent of material wealth (economic growth and livelihood) to also include other constituents, including: the ability to be adequately nourished; the ability to have access to freshwater; and the ability to have access to energy to keep warm and to cook, among others (Duraiappah 2004). Like ecosystem services, we only report on human well-being constituents directly or indirectly related to ecosystem services and, hence, this report should not be viewed as a comprehensive survey of all constituents of human well-being.

While not exhaustive, this overview does point out what ecosystem services and constituents of human well-being are most in need of attention and where they are located at the regional level. By taking this unique approach and using a finer spatial lens, areas where well-being and ecosystems are stressed emerge and clarify difficult trade-offs being made at the local level.

This report is organized into four sections with the first briefly describing the people and landscape of Mali, thus providing a backdrop for the rest of the overview. Section 2 scopes out the main ecological

services stressed and pinpoints their locations. Section 3 then discusses the related constituents of well-being that are increasingly being threatened by these deteriorating ecosystem services and, as with ecosystem services, locates them. The concluding section collocates those regions where ecosystem services are stressed with those where the constituents of human well-being are threatened and then briefly outlines the more outstanding trade-offs being made.

Figure 1. The links among ecosystem services and human well-being

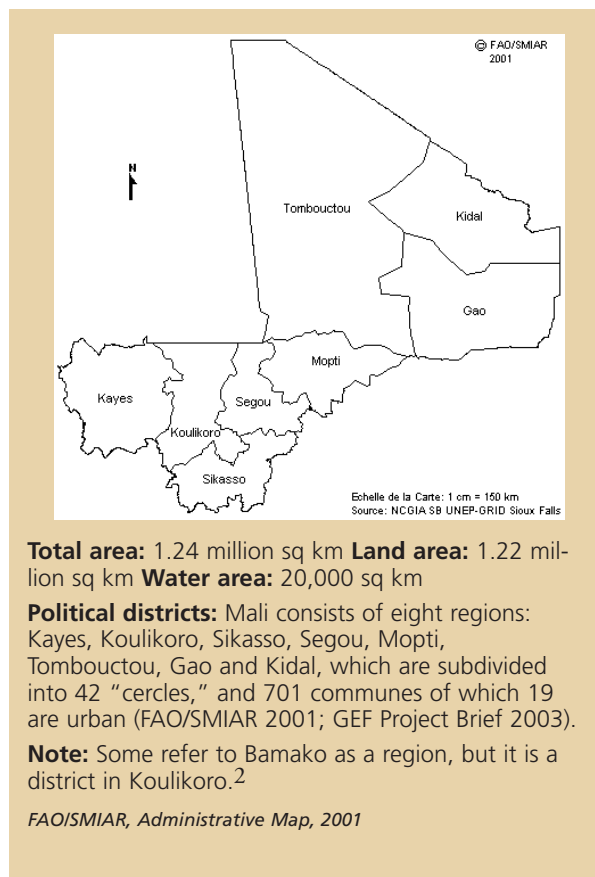


(Source: Duraiappah 2002)

1. Mali in Brief

Mali, a landlocked country with a mainly rural population, “is traditionally divided in two; the nomadic areas of the Sahara and the Sahel and the agricultural region to the south” (Oxfam *et al.* 2002). It is inhabited by diverse groups of people including nomadic groups such as the Tuareg and Moors; the Bambara who live along the Niger River; Soninke, who are descended from founders of the Ghana empire; the Malinke, descendants of the Malian empire; the Dogon and others. Mali was a commercial and cultural centre from the 13th century when the Malinke empire dominated trade routes crossing northern and western Africa. Its decline began in 1594 due to invasions from rival states. It was later colonized by France and achieved independence in 1960, but has since experienced numerous political problems and internal conflicts (Oxfam *et al.* 2002).

Map 1. Regions of Mali



1.1 Physical geography and natural environment

Mali is a landlocked country in northwest Africa bisected by the southern portion of the Sahara Desert. It is divided into five vegetation/climatic zones:

1. northern arid Saharan zone, covering 30 per cent of the country, where rainfall is less than 50 mm per year;
2. sub-desert tropical steppe with annual rainfall of 50–200 mm, covering 21 per cent of the country;
3. semi-arid Sahelian zone dominated by tropical shrub land with rainfall ranging from 200 to 500 mm and covering 16 per cent of the country;
4. Sudanian savannah, comprising savannah park and grass savannah, covering 27 per cent of the country, with rainfall ranging from 500 to 1,200 mm per year; and
5. Guinean savannah of either trees or bush with areas of dry closed forest and gallery forest, which is in the south where annual rainfall can exceed 1,200 mm. This zone covers six per cent of the country.

(Kone 2001, 2; FAO. Forestry Department 2002; United States Central Intelligence Agency 2004).

These zones are home to four distinct ecosystems: sparse or barren vegetation in the north covers 51 per cent of total land area; shrub lands, savannah and grasslands cover 45 per cent in the centre; a cropland and natural vegetation mosaic covers three per cent in the south; and small wetlands or water bodies cover the remaining two per cent (World Resources Institute 2004c).

Climate: Annual precipitation is less than 50 mm in the arid north, gradually increasing to more than 1,200 mm in the subtropical south (Kone 2001, 2; FAO/SMIAR 2000a). In the central grasslands of Mopti, Segou and Koulikoro, intermittent drought is common, increasing the risk of desertification (Matthews and Morrow 1995), defined as “a process

² <http://www.un.org/Depts/Cartographic/map/profile/mali.pdf>

of land degradation, declining soil nutrient quality and soil loss characteristic of semi-arid conditions” (MSN Encarta 2005; FAO Forestry Department 1993). The hot dry season lasts from February to June, then becomes a mild wet season from June to October, and finally turns into a cool dry season from October to February (FAO/SMIAR 2000b; United States Central Intelligence Agency 2004).

Topography: Mali is mainly flat; the northern plain is comprised of mostly rolling hills covered with sand, while the south consists of savannah. The average altitude is 500 m above sea level with the lowest point being the Senegal River at 23 m and the highest, Hombori Tondo, at 1,155 m (United States Central Intelligence Agency 2004).

Hydrology: Mali’s southern portion is covered by two major drainage basins: the Niger River system which proceeds northeast towards the Inner Delta area where it joins with an important tributary, the Bani River; and the Senegal River system in the southwest (FAO Agriculture Department 1997). The southern Sahelian zone (consisting of the regions of Kayes, Koulikoro, Segou and Mopti) is in a huge flood plain that experiences frequent flooding and temporally and spatially varied surface water conditions.

Arable Land: Arable land, found along the banks of the Niger River in the Kayes, Koulikoro, Segou, Mopti and Sikasso regions, is limited, and covers only 3.7 per cent of the total country’s area (World Resources Institute 2003; FAO 1998; United States Department of State 2005). However, approximately 14 per cent of the land in Mali can potentially be cultivated, with roughly one third of this (or 325,030 sq km) actually being cultivated (FAO/SMIAR 2000a).

1.2 Demographics

Over time, Mali has been inhabited by peoples from several different ethnic groups, each speaking their own language and traditionally tied to specific occupations. “The Bambara, Malinke, and Dogon are farmers; the Fulani, Maur and Tuareg are herders; the Saracolés are traders; while the Bozo are fishers,” though these traditional ways of life have shifted in recent years, as people have sought diverse, non-traditional sources of income (United States Department of State 2005). Good relations among these groups were facilitated by easy mobility on the Niger River and across the country’s savannahs, and by the fact that 80 per cent of the people communicate in Bambara, the common language of the marketplace

(United States Department of State 2005). The exceptions are the Tuaregs and Maurs, desert nomads living in the north, who are related to the North African Berbers. The Tuaregs have traditionally opposed the central government and have staged armed uprisings to fight for more autonomy (United States Department of State 2005). Almost 90 per cent of the population, though, is concentrated in the south “on 30 per cent of the territory, in the Kayes, Koulikoro, Sikasso, Segou and Mopti regions and the Bamako District” (Global Environment Facility 2003, 9).

Box 1. The demographics of Mali

Population (2004 estimates):

Total:	11,965,788
0–14 years:	47.1%
15–64 years:	49.9%
65 years and over:	3.0%

Life expectancy at birth (2004 estimates):

Total average:	45.28 years
Male:	44.70 years
Female:	45.87 years

Fertility rate (2000–2005):

Number of births per woman:	7.0
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Annual population growth rate:

Per cent per year, 1975–2002:	2.6
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Population density (2002 estimates):

Average:	9.5 people/sq km
Most dense region:	>66 people/sq km
Sikasso, Segou, Mopti, 1990	
Least dense regions:	<6 people/sq km
Gao and Kidal, 1990	

Ethnic groups:

Mande (Bambara, Malinke, Soninke):	50%
Peul:	17%
Voltaic:	12%
Songhai:	6%
Tuareg and Moor:	10%
Other:	5%

Languages:

French (official)	
Bambara 80%	
Numerous African languages	

(United States Central Intelligence Agency 2004; United Nations Development Programme 2004; Africa Information Centre 2003; FAO/SMIAR 2000).

1.3 Economy: observable constraints

During the period 1994–2000, Mali’s economy experienced a robust 5.2 per cent average rate of growth, and per capita GDP growth remained steady at 1.16

per cent, increasing to 1.3 per cent by 2002 (Mali 2002; Norwegian UN Association *et al.* 2002). In 2004, however, economic growth slowed to 2.2 per cent, much less than in 2003 when growth was 7.4 per cent, but should reach 5.7 per cent in 2005 (OECD and African Development Bank 2005, 293). Mali's recent economic performance has been hindered by its vulnerability to exogenous factors, including export commodity prices, trade losses and a Sahel locust infestation (OECD and African Development Bank 2005).

Despite its rich culture and history, Mali remains desperately poor and continues to experience environmental problems such as the recent locust invasion, recurrent drought and the encroachment of the Sahara desert. The country is also vulnerable to economic

shocks, as literacy rates are low and most people are subsistence farmers and fishers, making economic diversification efforts, for example, more challenging.

Not only is Mali one of the poorest countries in the world with a highly unequal distribution of income rendering it heavily dependent on foreign aid, but its economy is vulnerable to world prices of cotton and gold (OECD and African Development Bank 2005, 293). Unfortunately, recent low world prices for cotton have severely affected the terms of trade of this primary export (OECD and African Development Bank 2005). In addition to low prices for cotton, worker payments and external trade routes have been threatened by continued unrest in neighbouring Côte d'Ivoire, Mali's principal trading partner (United States Department of State 2005).

Box 2. Development and macro-economic indicators

Natural resources:

Gold, limestone, uranium, hydropower.

Note: bauxite, iron ore, manganese, tin and copper deposits known but not exploited.

GDP (constant 1995 US dollars), (2003): US\$4,326 million

Allocation of GDP by sector (2003):

Services (including government services):	39%
Agriculture and livestock:	29%
Mining:	11%
Manufacturing:	8%
Construction, electricity and water:	7%
Fishing and forestry:	6%

Main foreign exchange by sector (2000):

Imports: US\$952 million: Food, machinery, spare parts, vehicles, petroleum products, chemicals, pharmaceuticals and textiles. Industrial activity is confined largely to processing farm commodities).

Food aid constitutes 10% of total imports.

Exports: US\$629: Cotton, gold, livestock, fish, tannery products, groundnuts and diamonds. There is mining for phosphate but the industrial sector is undeveloped.

Main employment sector:

Agriculture and fishing employ 85.8% of the total labour force.

Per capita annual income: US\$240³

Income distribution (2002):

Gini coefficient:	51 (100% is perfect inequity)
Percentage of total income earned by richest 20% of population:	56.2%
Percentage of total income earned by poorest 20% of population:	4.6%

Adult literacy rate (per cent ages 15 and above):

19%

Human Development Index (HDI) value:

0.326

Human Development Index (HDI) rank (out of 177):

174

(OECD and African Development Bank 2005; World Bank 2005; African Forum and Network on Debt and Development 2003; United Nations Development Programme 2004; United States Central Intelligence Agency 2004; United States Department of State 2005; Mali 2002; World Resources Institute 2003; World Resources Institute 2003b).

³ This is well below the average of US\$510 for Sub-Saharan Africa in 1998.

2. State of Ecosystem Services

A literature review identified maintenance of biodiversity; food production; water supply, purification and regulation; and fuel provision as the four critical ecosystem services deteriorating in Mali. We discuss each in detail below, outline some of the main factors influencing their deterioration and, where possible, identify the regions in which they are declining. We use an ecosystem service approach in order to capture more explicitly the trade-offs and synergies among services.

2.1 Biodiversity

Only very recently has theoretical and empirical work identified linkages between changes in biodiversity and the way ecosystems function (Schulze and Mooney 1993; Loreau, Naeem and Inchausti 2002). The common perception of the value of biodiversity is limited to specific uses of a limited number of specific species by humans. However, there is increasing theoretical and empirical evidence of a much more complex relationship between biodiversity—defined as the variability among living organisms; this includes diversity within species, between species and of ecosystems—and ecosystem services. Species perform numerous services for ecosystems; for example, in many ecosystems, there are a variety of species that fix nitrogen in the soil. The importance of the composition of the species is determined by how much a loss in the ecosystem service is experienced when one or more of the species is lost. The lower the impact of a loss of a species on ecosystem functions, the higher is the level of redundancy in the system.

Status of biodiversity

Diverse ecosystems, ranging from closed forests, shrub lands, grasslands, wetlands and arid areas, can be found within the borders of Mali and over 6,115 sq km of the area (3.8 per cent) is legally protected (Global Environment Facility 2003, 10). All protected areas include: the Boucle du Baoule Complex (3,500 sq km, composed of the Boucle du Baoule National Park, the Fina Reserve, Badinko Reserve and the Kongosambougou Reserve); 160 km northwest of Bamako; the Douentza Elephant Reserve (12,000 sq km) in Gao; the Ansongo-Menaka Giraffe Reserve (17,500 sq km); the Faya classified forest (800 sq km)

east of Bamako; and about 100 other classified forests totalling 7,160 sq km (Global Environment Facility 2003, 10). These protected areas are in Kayes, Koulikoro, Mopti, southern Tombouctou and Gao (FAO Forestry Department 2002). In addition, there are three Ramsar wetland sites of international importance; two are located in Mopti and one in Tombouctou and they cover 162,000 ha located in the Inner Niger Delta (Global Environment Facility 2003).

The Mopti Region contains two interdependent agro-ecological zones where both vegetative cover and soils are highly degraded (Global Environment Facility 2003, 8). Here, the Inner Niger Delta, a rare large inland delta characterized by diverse, complex and productive ecosystems, covers 30,000 sq km of this region; it is a refuge for migratory and water birds such as the crown crane, purple heron and cormorant, and home to several endemic and often endangered species, including manatees and hippopotami, and 138 species of fish, 24 of which are endemic (Global Environment Facility 2003). This area also is an important source of agro-diversity where traditional wild rice is harvested by local producers along with over 20 other varieties of cultivated rice (Global Environment Facility 2003). Moreover, it harbours native breeds of farm animals, including the Macina wood sheep and the peul zebu known for its resistance to wet environments (Global Environment Facility 2003).

Forests cover less than 26 per cent of the country and contain numerous endemic and other species, but are largely degraded (Kone 2001, 5; Global Environment Facility 2003). These southern forests, mainly in Kayes, Koulikoro, Sikasso and Segou, are not only vital sources of biodiversity, but also provide woodfuel, timber and non-timber forest products such as fruits, nuts, baobab leaves, raffia, fodder for livestock, bush meat, medicinal plants, honey, beeswax and edible oils (Kone 2001, 4; FAO Forestry Department 2002). In some areas, they are part of agricultural production systems; many communities depend on wild animals not only for food, but also for medicinal purposes (World Rainforest Movement 2001).

Biodiversity in the Sahel ecosystem, which contains lakes, dunes, low-land forests and inselbergs and, in the

case of Mali, “the world’s northernmost 700-strong elephant population,” is also threatened (World Bank 2002, 4). For example, the Gourma area, which is located between the Niger River bend and the Burkina border and spans Mopti, Tombouctou and Gao regions, is experiencing local extinction of flora and fauna along with desertification (World Bank 2002, 4).

The 2004 IUCN Red List of Threatened Species shows 18 threatened in Mali with 13 of these being mammals (IUCN 2005).

Factors influencing biodiversity loss

Forest biodiversity is threatened by a combination of factors including climatic hazards such as drought, slash and burn agriculture, woodfuel consumption, bush fire, illegal hunting and population growth (Kone 2001, 6; Global Environment Facility 2003). The Ministry of the Environment estimates that Mali loses 400,000 ha of tree cover annually to meet woodfuel and timber demands (United Nations Integrated Regional Information Network 2005). As well, Mali’s forest resources face immense pressure to be cleared for agricultural purposes.

The expansion of agriculture, partly driven by population growth, also adversely affects semi-aquatic ecosystems along the Niger River in irrigated rice growing areas by destroying wetland wild and native plant species (Mali 2002; Global Environment Facility 2001). The modification of traditional transhumant livestock corridors and subsequent dissolution of traditional natural resource management systems has led to conflicts in accessing resources and further destruction of natural habitat in the Inner Delta (Global Environment Facility 2001). In addition to expanding agriculture and woodfuel demand, drought and inadequate flooding dams, water diversion projects, over-grazing and over-exploitation of fish and water birds threaten the Ramsar-protected wetland areas (Global Environment Facility 2003).

In some areas, such as Niamakoroni community on the Mande plateau of south-central Mali (35 km from Bamako in Koulikoro), the expansion of men’s market gardening is leading to the decrease in available local plants for the diet. Garden plants maintained by men are associated with urban consumers, and are replacing the local plants that women grow for local consumption. In fact, men often see the plants women grow, such as traditional leafy crops and sauce plants, as weeds to be replaced with tomato and banana income-earners, thus threatening local plant biodiversity.

Without local gardens, women are increasingly exploiting surrounding bush-based plant resources, and tending to over-exploit these wild plants (Wooten 2004).

Regions most affected by biodiversity loss

- Gao: local extinction of flora and fauna along with desertification
- Kayes: forest degradation
- Koulikoro: forest degradation
- Mopti: local extinction of flora and fauna along with desertification; forest degradation
- Sikasso: forest degradation
- Segou: forest degradation
- Tombouctou: local extinction of flora and fauna along with desertification

2.2 Food and fibre provision

Ecosystems provide the medium for growing the food on which humans and domesticated animals are dependent. This includes the vast range of food products derived from plants, animals and microbes. If the cultivation of plants for food and livestock is to succeed, then natural factors such as fertile soils, adequate soil moisture, suitable climatic conditions and a rich source of plant and animal species are necessary. Deficiencies in some of these elements or attributes can be augmented by technology through the use of fertilizers, irrigated water, high-yielding seeds and domesticated animals over the short term and for longer periods if managed sustainably.

State of food and fibre provision

Agriculture is dominated by small-scale, rain-fed subsistence cultivation with frequent low and irregular yields (Global Environment Facility 2003). Subsistence crops comprise about 90 per cent of the 1.4 million ha under cultivation in the Sahelian zone, with the principal food crops being cereals, primarily sorghum, millet and maize (United States Department of State 2005; Global Environment Facility 2003).

Domestic food production is marked by variability. Between 1980 and 2001, average cereal crop yield increased by 38 per cent to 1,113 kg/ha and production grew by 149 per cent, a per capita increase of 50 per cent, while cereal prices remained stable (World Resources Institute 2003; FEWS 2000; FAO 1998).

Currently, however, per capita food production has declined to 96.3 per cent of 1999–2001 levels leading to a loss in grain self-sufficiency; cereal production of 237 tons per capita meets only 96 per cent of total consumption with the gap being filled by imported food aid (World Resources Institute 2003).

In addition to cereals, livestock are an important source of food and there is a strong link between crop and livestock production; crops provide unmarketable surpluses and by-products that livestock can convert into high-value products. In 2001, Malians kept an estimated six million cattle, 13 million goats/sheep and 300,000 camels with the highest concentration of bovine livestock occurring in Mopti Region, north of Bamako, and in Segou, where over 100 animals per sq km can be found (Global Environment Facility 2003; FAO; United States Department of State 2005). Transhumant livestock systems are more common in the north where nomadic pastoralists, such as the Tuaregs, depend on milk and meat from cattle, sheep and goats (FAO/SMIAR 2000; CIA 2004). Crop and livestock production is intertwined in several ways. In central Mali, the cattle herd is used to fertilize crop fields, while in Dilaba farmers apply composted household waste with cow dung and small ruminant droppings to their fields, particularly in drought times (FAO 2001). Large herds of cattle, sheep and goats graze agricultural residue and animal traction is also important in cotton production and its use has risen to 90 per cent (Yevich 2003; International Food Policy Research Institute 2000).

Malian communities along the Niger River, the primary source of fish, rely on this source of protein for food and also income, as the surplus is smoked, salted and dried for export (United States Department of State 2005). Here, tilapia and clarias are important catches and in 2000, total freshwater catch was 109,870 metric tons (Global Environment Facility 2003; World Resources Institute 2003a). Due to drought and water diversion for agriculture, fish production has declined steadily since the early 1980s (U.S. Department of State 2005).

In addition to cultivated and husbanded food sources, a wide variety of plants and animals in the forest provide important food resources (World Rainforest Movement 2001). The “hidden harvest” from savannahs and forests in Mali provide essential dietary products, such as the fruit of the *Saba senegalensis* which is widely eaten (World Rainforest

Movement 2001). Wild animals, from mammals to insects, provide an important source of protein for rural and urban households (World Rainforest Movement 2001).

Cotton production contributes eight per cent of GDP and “about 3.3 million people live directly from its cultivation” (OECD and African Development Bank 2005, 294). In addition, the cotton sector contributes to rural development generally and aids in the cultivation of cereal crops that use the same inputs. Production of cotton remains high, though a fall in world market prices has resulted in losses for most (OECD and African Development Bank 2005, 294).

Factors influencing deterioration in food and fibre provision

Several natural factors constrain food and fibre provision, particularly persistent natural disasters such as drought, floods and locusts, as well as irregular rain patterns. There is limited land area to support permanent cultivation, as 65 per cent of Mali’s land area is desert or semi-desert that is almost completely barren of vegetation, restricting agricultural activity to riverine areas irrigated primarily by the Niger (Mali 2002; Global Environment Facility 2003; FAO 1998). In addition, food production is temporally restricted, as it can only be practised for a quarter of the year (N’Djim and Doumbia 1996).

The recurrent droughts that have plagued Mali for several decades are yet another constraint as is desertification. One third of the country is seriously threatened by desertification and the Sahara desert is expanding southward at a distressing rate (FAO Forestry Department 1993; MSN Encarta 2005).

Exacerbating natural susceptibilities, increasing population pressures and the persistence of extensive systems of production involving uncontrolled clear-cutting for firewood, timber or cropland, over-grazing and bushfires have degraded the natural resource base for the majority of rural populations, while intensifying and expanding agriculture have led to land degradation (Global Environment Facility 2003). In this pattern of expansion, farmers reduce fallow periods and apply insufficient organic fertilizer which contributes to soil fertility loss (Tefft 2004; Tarawali and Ogunbile 1995). Other factors contributing to soil degradation and desertification are deforestation and increased farming of marginal lands (Tarawali and Ogunbile 1995). In some areas, irrigation has led to soil salinization and this problem has been worsened

by the shift from cotton to rice production, and the consequent increased irrigation demands (Valenza *et al.* 2000 in British Geological Survey 2002). Over three decades, soil degradation has led to a decrease in the area that is flooded by roughly 30–50 per cent.

Drought has seriously affected livestock production and nomadic herders, such as the Tuaregs (Refugees International 2004). Rainfall deficits of just 100–200 mm decrease the water level of the Niger River by 50–60 cm, resulting in lower soil fertility and changes in pasture flora (FAO. Forestry Department 1993). The degradation of pastures, vegetative cover and livestock corridors, as well as reduced water availability, has led pastoralists to remain for increasingly long periods of time around semi-permanent or permanent water sources, leading to considerable damage to the land from over-grazing and trimming (Global Environment Facility 2003). Increased woodfuel collection in settled areas has further compromised an important livestock browse, *Pterocarpus lucens* (Vermeulen, 2001). In general, lack of infrastructure, lack of land security, and inadequate financing and training plague food production services (Mali 2002).

Regions most affected by deterioration in food and fibre provision

The Interior Delta of the Niger of Mopti Region contains 70 per cent of the country's best agricultural land; 50 per cent of the nation's cattle; and provides 80 per cent of its fish catch, however, crop losses are recorded here as well as in Gao (Global Environment Facility 2001). Of the two regions, Mopti was hardest hit, losing more than 100,000 ha of crops due to an extended dry spell or the poor sequencing of rains and floods (Famine Early Warning System Network 2000). Bandiagara Cercle in Mopti Region was especially affected as millet and fonio withered due to lack of rain. When the Niger River rose in Mopti's Bankass and Djenne Cercles, the rice crop that was planted late due to dry spells was then flooded before it was properly emerged (Famine Early Warning System Network 2000). In Gao Region, Bourem and Ansongo Cercles lost crops due to poor rainfall as well as flooding before the rice had emerged, affecting 7,408 ha of rice, 1,000 ha of millet and 1,525 ha of sorghum (Famine Early Warning System Network 2000). Crop losses caused by dry conditions were less significant in other regions, but Kayes, Segou and Tombouctou regions also reported cases of withered maize and late-sown millet and sorghum (Famine

Early Warning System Network 2000). Most recently, drought and/or locusts have adversely affected the northern edge of Mali's main farming regions (Famine Early Warning System Network 2004). In the Southern Sudan belt (Sikassa, Koulikoro, Segou and Kayes), there is also a severe decline in soil fertility (Global Environment Facility 2003; Global Environment Facility 2005).

- Gao: crop losses due to poor rainfall and then flooding
- Kayes: crop losses due to dry conditions; severe decline in soil fertility
- Koulikoro: severe decline in soil fertility
- Mopti: crop losses due to poor rainfall and then flooding
- Segou: crop losses due to dry conditions; severe decline in soil fertility
- Sikasso: severe decline in soil fertility
- Tombouctou: crop losses due to dry conditions

2.3 Water supply purification and regulation

Ecosystems play a key role in providing clean freshwater and regulating the flow of water. The effectiveness of ecosystems to provide these services is determined largely by the quality of the country's watersheds (see Box 3).

Box 3. What is a watershed?

A watershed is the area of land that catches rain and snow (if applicable) and drains or seeps these into a marsh, stream, river, lake or groundwater. Their primary function is to capture, store and safely release water. This function is indicated by The Internal Renewable Water Resource (IRWR). For example, as snow melts on mountain peaks in the spring, much of the water soaks into the ground, replenishing soil moisture and groundwater. This water will be a source of flow to local streams and rivers during dry seasons. Healthy soils and vegetation in the watershed are essential to proper watershed functioning (Donaldson and Swanson 2001).

Mali's main source of surface water is the Niger and Senegal rivers, providing a total annual flow of about 56.5 billion cu m or some 8,320 cu m per capita (N'Djim and Doumbia 1996; World Resources

Institute 2003c). The country is most dependent on the Niger River for water; this river basin covers 578,850 sq km, or 46.7 per cent of the country, and receives an average of 440 mm of rainfall annually (FAO Agriculture Department 1997). Through the Niger, 40 cu km/yr of water enters Mali from Guinea and its irrigation potential is estimated at 556,000 ha (FAO 1997). The Senegal River basin covers 11.2 per cent of the country and captures an average of 855 mm precipitation annually, but frequently is dry (FAO Agriculture Department 1997).

Mali also possesses internally renewable water resources including rainwater and groundwater. In 2001, these sources provided 60 cu km, or 4,992 cu m of water per person (World Resources Institute 2003c). Groundwater is important to the capital city of Bamako, Koulikoro, where 55 per cent of the population depends on water from aquifers (British Geological Survey, 2002).

Although Mali's water potential is broadly sufficient to meet its theoretical annual needs of approximately 6.12 billion cu m, assuming 62 million for humans, 60 million for cattle and six billion for irrigation, water supply availability and access vary substantially across the country (N'Djim and Doumbia 1996). Unfortunately, the poorer aquifers with less permeability and storage capacity are prevalent in the south, where the population is mainly concentrated (British Geological Survey, 2002). In general, Mali suffers from restricted access to water due to its uneven temporal and geographical distribution (N'Djim and Doumbia 1996). As a result, water resources are very poorly exploited, with only 0.2 per cent of underground water and 12 per cent of surface water being utilized (N'Djim and Doumbia 1996).

State of freshwater supply purification and regulation services

Due to uneven and irregular supply, less than half of the population (46 per cent) has access to potable water and Mali's water resources are generally under-utilized (N'Djim and Doumbia 1996). Agriculture uses 97 per cent of water withdrawals, followed distantly by domestic (two per cent) and industrial use (one per cent) (World Resources Institute 2003c). The total withdrawal rate is 1.4 cu km per year, or 167 cu m per capita, only two per cent of actual renewable water resources (World Resources Institute 2003c). In fact, although Mali's rate of water use (in cu km/yr) is the seventh highest in Africa, it uses only 6.9 per cent of its total water resources (FAO Land

and Water Development Division 2001). Though this data suggest opportunities for better water supply, researchers anticipate a substantial decline of 52 per cent in water supply from 1990 to 2020 (N'Djim and Doumbia 1996).

There is an incredible reduction in the quantity of water in the Niger at the Inner Delta due to natural seepage and evaporation combined with next to no runoff from the entire left bank (FAO Agriculture Department 1997). A marked decrease in water volume as well as reduced floodwater have also been noted in the Bani River, which drains into the Niger, curtailing agriculture production, increasing hardship in the Segou area and leading to emigration to other regions (Fisher, Meierotto and Russel 2001, 2).

Not only is water access a growing concern—so is water quality. Although there are few data to assess the inorganic quality of Mali groundwater, increasing salinity has been observed in several aquifers (British Geological Survey 2002). In Bamako, chemical and biological contamination of groundwater is evident, including high concentrations of dissolved salts (chloride and nitrates) and bacteriological pollution making water unfit for human consumption (Shearer 2003). Due to inadequate access to water supply, water in rivers and wells is often contaminated with bacteria and water quality, and quantity problems are a significant cause of death and disease (N'Djim and Doumbia 1996).

Lastly, the ecosystem's provision of regulated water is often unreliable. In some areas, the groundwater level has risen by several metres and in 2003, 10,000 lost their homes in Mopti and Segou as a result of heavy rains and floods (Global Environment Facility 2005; ReliefWeb 2003). Wetlands that would attenuate flood surges and form sinks and sources for runoff, are being degraded, aggravating water regulation problems.

Factors influencing water supply, purification and regulation services

Poor land management practices and deforestation have exacerbated natural limitations in water distribution and supply (N'Djim and Doumbia 1996). To compensate for rainfall deficits, farmers cultivate areas around permanent waterholes such as backwaters, streams and rivers, a practice that silts up and eventually fills the river beds with fertile soil from fields, thus reducing the lifespan of the water course (N'Djim and Doumbia 1996). Reduced forest cover also accel-

erates soil erosion and stream siltation (N'Djim and Doumbia 1996).

Water quality is adversely affected by chemical agricultural inputs, irrigation practices and the poor regulation and disposal of waste. For example, at least 85,000 litres of expired pesticides are inappropriately stored in northern Mali and have leaked into the water sources (United Nations Office for the Coordination of Humanitarian Affairs 2001). Irrigation practices have led to high alkalinity and the salinization of surface and shallow groundwater in Mali's river valleys (British Geological Survey 2002). Water is also contaminated by widespread unregulated dumping of domestic waste; 95 per cent of households use unhygienic sewage disposal practices (Mali 2002). Unfortunately, only eight per cent of households in Mali have installations that adequately dispose of excreta and pollution from the daily production and poor disposal of waste is a problem particularly in the shanty towns of unregulated urban or peri-urban areas (Mali 2002). Poor urban sanitation has also led to nitrate and other pollution of surface water and shallow groundwater sources (British Geological Survey 2002). Water pollution, however, also arises from industrial, craft, transportation and agricultural activities (Mali 2002).

Regions most affected by deterioration in freshwater supply, purification and regulation

Water quality is stressed throughout the country. In general, lack of water quality is a more pronounced problem in urban centres which face high concentrations of nitrate from pollution in their water (British Geological Survey 2002). In the north (Tombouctou, Kidal and Gao), as well as in the central area of Office du Niger (in Segou and Mopti regions), pesticide contamination and pollution from intensive farming areas are problems (Global Environment Facility 2005). Groundwater salinization from agriculture along the Niger River and the Fala of Molodo, west of the Niger, also has a significant negative impact on water potability in the south river valley (British Geological Survey 2002).

Water supply is low in western, central and northern areas. Kayes and Koulikoro have the lowest well-sinking success, and Koulikoro and Segou have the lowest average groundwater debit rate (cu m/hour) (N'Djim and Doumbia 1996). Tombouctou, Kidal and Gao have limited surface water.

Water regulation is a problem in the central regions; in Segou and Mopti, groundwater level has risen from soil degradation (Global Environment Facility 2005). Flooding also is a problem in the central region, where in 2002, floods occurred in Bamako District (Koulikoro), Tombouctou and Gao and in 2001, floods occurred in Sikasso, Kidal, Mopti, and Koulikoro as well (Asian Disaster Reduction Center *et al.* 2002).

Regions most affected: Water supply, purification and regulation services are deteriorating in all regions.

2.4 Fuel provision

Traditional biological fuels, particularly wood and charcoal, comprise 88.9 per cent of total energy use and 93 per cent of all households use firewood for fuel (N'Djim and Doumbia 1996; MSN Encarta 2005). According to Mali's Ministry of the Environment, the country's population consumes six million tons of wood per year and has one of the highest woodfuel consumption rates in the Sahel at 1.49 kg/day (United Nations Integrated Regional Information Network 2004; Yevich 2003). In 2000, natural and plantation forest covered 10.8 per cent or 13.2 million ha of the country's land area with plantations covering 14,000 ha and natural forest covering 99 per cent of total forest area (FAO Forestry Department 2003; World Resources Institute 2004c). Most of this forest is open and fragmented, and entirely concentrated in the south (FAO Forestry Department 2003).

State of fuel as an ecosystem service

The annual deforestation rate in Mali is at least 0.8 per cent, continually decreasing the primary source of woodfuel for domestic use (World Bank 1997). From 1990 to 2000, total forest area decreased by seven per cent, despite the fact that the area dedicated to plantations grew by seven per cent (World Resources Institute 2004c). Currently, average annual consumption of woodfuel is 650–750 kg/person and is projected to be 18 million tons by 2020, resulting in deforestation across 14 per cent of the national land area, which, by some estimates, is more than the available forest cover (N'Djim and Doumbia 1996). Since only 2.3 per cent of the current tropical forest is protected, woodfuel shortages can only worsen (World Resources Institute 2004c).

Approximately 40 per cent of crop residue is either burned as household fuel or as trash in the field

(Yevich 2003). It appears, however, that in the south and west where the population is concentrated, there is a “sufficient-to-surplus” of woodfuel and alternative biofuels such as crop residue and dung are less common sources of household energy (Yevich 2003).

In urban areas especially, charcoal is being used more regularly as a household fuel source. One example is Bamako where charcoal has recently replaced wood as the primary fuel (FAO Forestry Department 2002). While it could be assumed that improving charcoal production may reduce its impact on forested areas, in Mali one ton of charcoal requires seven tons of wood and the quantity of wood needed to make charcoal has increased from 600,000 tons in 1994 to 1,200,000 tons in 2000 (FAO Forestry Department, 2002; FAO 1999; Foley, Kerkhof and Madougou 2002).

Factors influencing decline in biological fuel services

Mali’s forests face extensive cutting for domestic energy along with other causes of deforestation such as heavy pressure from cropping, grazing and bush fires (Mali 2002; FAO Forestry Department 2003).⁴ These factors are compounded by persistent drought and a human population growth rate of over two per

cent (FAO Forestry Department, 2003). Another factor is unauthorized logging and charcoal exportation to neighbouring countries like Mauritania (United Nations Integrated Regional Information Network 2004). In general, a lack of community participation in natural resource management, technical strength in local government bodies, and unfavourable centralized institutional structure and land tenure contribute to the loss of forests (FAO Forestry Department 2003; Cuny 2001).

Regions most affected by deterioration in biological fuel services

Ninety per cent of Mali’s population is concentrated on 30 per cent of its territory in Kayes, Koulikoro, Sikasso, Segou and Mopti regions and Bamako district (Global Environment Facility 2003). Thus, natural forests in the northern edge of their range (Kayes, Koulikoro and Segou) are being depleted for woodfuel and charcoal, especially along access roads (World Bank 2002a; Global Environment Facility 1999). For example, in Kafela village, found in Sikasso Region, over-use of woodfuel for income and cooking is leading to heavy deforestation (Orosz *et al.* 2004).

⁴ It is possible to interpret woodfuel supply as being in a state of dynamic equilibrium rather than accelerating toward collapse (UNDP/World Bank 2001). It is worth noting that by some accounts, woodfuel consumption is not a substantiated cause of deforestation, and many other factors, including agriculture, fire, grazing and climate change play a more demonstrated role in deforestation than woodfuel collection (Ribot, 1999). The “crisis” scenarios of woodfuel shortage and deforestation in the West African drylands are not well-supported by data and may reflect colonial narratives, political motives and an inadequate recognition of the spatial and temporal nature of regeneration (Ribot 1999).

2.5 Summary of ecosystem services stresses

Mali has five distinct vegetative/climate regions, but there is a vast difference between the biodiverse forest along the Niger River in the south and that of the arid, barren desert in the north. This difference is reflected in settlement patterns, as most of the population lives in the southern part of the country where biodiversity is richest. Unfortunately, biodiversity is eroding and ecosystem services, such as food provision and water supply are deteriorating, due to repeated droughts, recent locust infestations and increasing pressures from population growth.

Of the four ecosystem services surveyed, all four were found to be deteriorating in four of the eight regions, namely Kayes, Koulikoro, Segou and Sikasso. Three ecosystem services were deteriorating in Gao, Mopti and Tombouctou. Kidal Region was the exception; this region is arid with little vegetation and sparsely populated. Biodiversity loss and threats to food and fibre provision and water supply, purification and regulation were found in all regions (except Kidal) illustrating a vulnerable situation for people and ecosystems. The survey of biological fuel (energy) supply was less conclusive, but found to be threatened in four of the regions.

Table 1. Ecosystem services stressed by region

Region	Ecosystem service stresses
Gao	Biodiversity loss Food production Water supply, purification and regulation
Kayes	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)
Kidal	Water supply, purification and regulation
Koulikoro	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)
Mopti	Biodiversity loss Food production Water supply, purification and regulation
Segou	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)
Sikasso	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)
Tombouctou	Biodiversity loss Food production Water supply, purification and regulation

3. State of Human Well-being in Mali

Human well-being is multi-dimensional with many constituents and determinants closely determined by the state of ecosystem services (Duraiappah 2004). However, not all constituents may be under serious threat in a country, and not all of these constituents are directly dependent on the state of ecosystem services. Therefore, as emphasized in the beginning, only constituents and/or determinants of well-being directly affected by the state of ecosystem services are addressed in this report. Our preliminary review identified the following critical constituents which appear to be under serious threat among many social groups within Mali.

3.1 Ability to be adequately nourished

The ability to be adequately nourished is dependent on two factors: the ability to grow food, as well as the ability to buy food. While the supply of food is critical, economic entitlements that individuals are able to secure, such as income from non-farm labour, are also important (Sen 1990). There are several measures of the ability to be adequately nourished including that of food (in)security as well as incidence of malnutrition among others.

State of ability to be adequately nourished

Maliens derive most of their caloric intake from cereals and rice (73 per cent), followed by oil (eight per cent); milk and eggs (five per cent); meat (four per cent); legumes (three per cent); fruits and vegetables (one per cent); and fish (0.5 per cent) (Mali 2002; FAO/SMIAR 2000b). Much of this is obtained through subsistence crop production, which dominates the agricultural economy, as well as the Malian economy as a whole. The average daily per capita calorie supply in 1999 was 2,314 kilocalories compared to the world average of 2,808 kilocalories. Chronic and acute malnutrition is found in 30 per cent of children under five years of age with 43 per cent of children being underweight (Amani, Kessy and Macha 2004, 162; World Resources Institute 2003, Global Environment Facility 2003).

Factors influencing the ability to be adequately nourished

One of the main factors influencing poor nourishment is inability to grow food. Food supply is characterized by variable agriculture production, uneven water supply, desertification and lack of economic entitlements. Consequently, Malians frequently experience shortfalls in grain production and have fewer available proteins and calories, resulting in significant recourse to food aid (FAO/SMIAR 2003). This is more evident in coarse grain producing regions, such as Mopti, where wasting rates for children are higher than rice and cotton growing areas and availability and access to food is an ongoing issue (Tefft and Kelly 2002, 3). There is a lower prevalence of wasting and stunting in children living in rice producing areas, though, which supports efforts to expand rice production in Mali. Indeed, rice consumption is growing by 5.6 per cent per annum (International Rice Research Institute 2005).

The ability to be nourished not only depends on food supply, but also on economic entitlements to buy food. Rising grain prices due to drought and/or locusts have affected most of the population, particularly agro-pastoralists and nomadic herders who are dependent on local markets to sell their livestock and purchase grains (Famine Early Warning System Network 2004). Between the start of 2004 and 2005, millet prices rose 33 per cent; rice 15 per cent; and corn 65 per cent (United Nations Integrated Regional Information Network 2005). Although “higher levels of household assets play a statistically significant role in promoting positive health and nutritional outcomes,” this was not the case in the higher income and food surplus cotton Sikasso Region, where child stunting is quite high (50 per cent for children 12–17 months) indicating that other factors, possibly cultural, are influencing the ability to be adequately nourished (Behrman and Deolalikar 1988 in Tefft and Kelly 2002, 3).

Regions most affected by inability to be adequately nourished

- Gao: food insecurity
- Kayes: drought and locust plague
- Kidal: food insecurity
- Koulikoro: drought and locust plague
- Mopti Region: food insecurity; drought and locust plague; grain price increases
- Segou: drought and locust plague; average price of millet in April 2001 was 56 per cent higher than the previous year and 30 per cent more than the average over the past five years
- Sikasso: high incidence of childhood stunting
- Tombouctou: food insecurity

3.2 Ability to access adequate clean water

Access to adequate and clean drinking water is essential for life. The minimum standard set by the United Nations for an individual to satisfy their basic needs is 1,000 cu m per year (Biggs *et al.* 2004, 13). Second, clean water is a necessary condition for a healthy life and to be protected against water-borne diseases like typhoid and cholera. Clean water can be provided in a number of ways. Filtration plants using modern technology provide clean water. But it is also well known that a watershed in pristine condition can offer the same quality of water. In a well known example, the city of New York was able to provide clean water to its habitants by restoring and preserving the Catskill watershed which basically captures, stores, purifies and releases water. The cost saved by preserving the watershed vis-à-vis building a modern water filtration plant was about \$4 billion (Daily and Ellison 2002; Duraiappah 2005).

State of ability to have adequate and clean drinking water

The quantity of freshwater per person has declined from 15,853 cu m in 1955 to 6,729 cu m in 1990 (N'Djim and Doumbia 1996). Even with this decline in per capita freshwater supply, Mali does not show serious water scarcity; however, in reality, only 49 per cent of the population has access to potable water and 63 per cent of the population is without access to safe water (N'Djim and Doumbia 1996; Mali 2000; African

Forum and Network on Debt and Development 2003). As well, since 1990, the proportion of the population with sustainable access to improved sanitation has actually dropped to 69 per cent (United Nations Development Programme 2004).

During the hot season (April to June), there is a resurgence of cholera, particularly, in the Mopti Region, which is most dependent on the Niger River (N'Djim and Doumbia 1996). River blindness (*Onchocercosis*) and diarrhea are two other water-related health problems that plague the country (N'Djim and Doumbia 1996).

Regions most affected by inability to have adequate and clean drinking water

The northern regions of Gao and Tombouctou have a lower than average percentage of the population with access to potable water. From among all regions, in Kidal, Tombouctou and Gao respectively, only three per cent; seven per cent; and eight per cent of the population has access to potable water (N'Djim and Doumbia 1996). These regions have the greatest portion of groundwater, but the least annual rainfall (N'Djim and Doumbia 1996).

Although urban areas face poorer water coverage, rural areas suffer a lower supply of potable water. In urban areas like Bamako in Koulikoro, only 40.5 per cent of the population has access to a clean modern water supply and the average water delivery service rate for all urban centres in Mali is 35 per cent (N'Djim and Doumbia 1996). By contrast, in rural areas, approximately 49 per cent of the population has potable water coverage, but the amount of potable water available in rural areas is lower (N'Djim and Doumbia 1996). In urban areas, 50 L of potable water per day per person is available, higher than both semi-urban (41 L) and rural areas (20 L) (N'Djim and Doumbia 1996).

Regions most threatened: Ability to have adequate and clean drinking water is threatened in all regions.

3.3 Ability to have energy to keep warm and cook

A reliable source of energy is a necessary component of human well-being; it is required for daily activities like cooking and keeping warm. The most important source of energy in Mali is wood; the total woodfuel consumption in 1996 was 6,315,000 cu m, and per

capita woodfuel consumption is 0.567 cu m/year (Amous 1999). Commercial primary energy consumption reflecting non-biofuels has actually declined since 1980 to 2001, from 20 to 17 kg oil equivalents per capita (Norwegian UN Association *et al.* 2000).

Firewood consumption is expanding more rapidly than its market supply (World Bank 2002a). Prices for woodfuel and charcoal are below market value such that rural producers subsidize urban consumption (World Bank and GEF 1999). Today, Malians are harvesting an increasing number of inferior woodfuel trees as well as fruit trees (such as the *Karite*, whose nuts contain a high fat content and are valuable in local diets), demonstrating an obvious shortage of wood resources (Cuny 2001).

Regions most affected by inability to have energy to keep warm and cook

Mali has major woodfuel shortages in the three northeastern regions: Gao, Tombouctou and Kidal (Yevich 2003). Sorobasso in Sikasso suffers from forest resource shortages (Cuny 2001).

3.4 Ability to earn a livelihood

The ability to earn a livelihood is essential to human well-being and is measured using various indicators such as per capita GDP, household consumption levels and so on. In efforts to identify those needing government supports, poverty lines or thresholds are established using an estimate of the cost of food and non-food basic needs for individuals and families.

State of ability to earn a livelihood

Mali's economic entitlements are low. In fact, 72.8 per cent of the population lives on less than \$1 a day, and 90.6 per cent lives on less than \$2 a day (World Resources Institute 2003b; Mali 2002). The public and private formal sector employs less than two per cent of the economically active population, and offers very few new jobs each year (Mali 2002).

Mali's rural population ranges between 80 and 90 per cent and most derive their livelihood from raising crops and livestock and by selling any surplus in the market (N'Djim and Doumbia 1996).

Commercial or cash crops, such as cotton, are an important source of income for local farmers and constitute a considerable portion of total export earn-

ings (United States Department of State 2005). Currently, almost 500,000 ha of land is designated for cotton production, mainly in the Southern Sudan belt or CMDT zone: Sikasso, southeastern Kayes, south Koulikoro and south Segou (Tefft 2004; Mali 2002). This crop is grown by 30 per cent of Malian households and earns 15 per cent of total government revenues and eight per cent of gross domestic product (Tefft, 2004). In addition, these households earn higher incomes, invest more in agriculture and produce up to 70 per cent more cereal per capita than non-cotton farmers (Tefft 2004). Their livelihoods, however, are very sensitive to macro-policy issues and external actors in the international cotton market (Hilhorst and Toulmin 1999). Due in part to agricultural subsidies in the United States, world cotton prices have fallen 50 per cent since the mid-1990s, resulting in a 1.7 per cent GDP decline in 2001–2002 along with eight per cent of its export earnings, losses that translate into US\$43 million (Oxfam 2002).

Animals are another source of income, savings and status, and the ownership of at least one pair of draft oxen is central to most livelihoods (Hilhorst and Toulmin 1999). Unfortunately, cattle are also exposed to climatic factors and their numbers are unlikely to reach pre-1990 drought levels due to increasing desertification in their range (MSN Encarta 2005). Fishing and aquaculture are yet another source of sustenance and income, employing 70,000 people. Total aquaculture production is 30 metric tons, but fish exports have declined 83 per cent since 1980 and Malians now import more fish than they export (World Resources Institute 2003a).

Regions most affected by inability to earn a livelihood (income poverty)

Eighty per cent of the poor are located in four main regions: Mopti, Sikasso, Segou and Koulikoro (Mali 2002). The central regions are the poorest, where the incidence of poverty is 76.2 per cent in Mopti (38.1 per cent are very poor) and 76.8 per cent in Timbouctou (26.1 per cent are very poor) (Global Environment Facility 2003). Although poverty remains a rural phenomenon, it is increasing in large towns due to the deteriorating labour market and migration to urban centres (Mali 2002).

The incidence of poverty is more than 50 per cent in all regions.

Table 2: Incidence and depth of poverty by region in 1998

Region	Total Incidence of Poverty (%) ⁵	Extent of Poverty (%) ⁶
Mali	63.8%	42.3%
Urban	30.1%	22.3%
Rural	75.9%	45.8%
Kayes	62.4%	43.9%
Koulikoro	59.5%	42.0%
Sikasso	65.8%	37.2%
Segou	68.2%	45.2%
Mopti	76.2%	53.1%
Timbuctu	76.8%	47.4%
Gao	78.7%	36.7%
Kidal	92.8%	32.7%
District of Bamako	28.6%	14.8%

(Mali 2002)

3.5 Summary of constituents of human well-being under threat

The abilities to be adequately nourished, access adequate and clean drinking water and earn a livelihood are threatened for a majority of the population in all regions of Mali. While there have been efforts to ease their plight, such as the expansion of rice cultivation, other factors over which there is little control have worked against them. Specifically, unpredictable climate, desertification and, in the case of cotton, international trade issues have all had detrimental impacts on their well-being. The extent of the challenges faced is eloquently described by such human development indicators as a life expectancy of 45 years and ranking as one of the poorest 10 countries in the world.

Table 3. Summary of constituents of human well-being under threat

Regions	Total Incidence of Poverty	Constituents Stressed
Gao	78.7%	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood
Kayes	62.4%	Adequately nourished Adequate and clean drinking water Earn a livelihood
Kidal	92.8%	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood
Koulikoro	59.5%	Adequately nourished Adequate and clean drinking water Earn a livelihood
Mopti	76.2%	Adequately nourished Adequate and clean drinking water Earn a livelihood
Segou	68.2%	Adequately nourished Adequate and clean drinking water Earn a livelihood
Sikasso	65.8%	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood
Tombouctou	76.8%	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood

5 “The measurement of poverty of living conditions was derived from the basis of a poverty index *I_s* calculated for each locality... This index varies from 0 points for the poorest locality to 20 points for the least poor locality... The incidence and depth of poverty by region... is determined by setting the line for poverty and extreme poverty respectively at 10 and 5 points for *I*” (Mali 2002).

6 “The extent of poverty is measured here as the investment effort needed by poor localities to obtain *I_s* equal to the poverty live of 10 points, as assessed at 42.3%” (Mali 2002).

4. Linking Ecosystem Services to Human Well-being

In Table 4, the ecosystem services stressed and constituents of human well-being threatened are listed for each region. Sikasso particularly stands out, as all four stressed ecosystem services and threatened constituents of well-being are present. Located in southern Mali, it is one of the most densely populated regions and contains arable land for cultivation as well as forests. The region is under considerable pressure, though, as indicated by the higher rate of forest degradation and loss of soil fertility as well as high rates of child stunting. Five regions, namely Gao, Kayes, Koulikoro, Segou and Tombouctou, are stressed and/or threatened in seven out of eight possible ecosystem services and constituents of well-being, faring only slightly better than Sikasso. Mopti has three ecosystem services stressed and three constituents threatened; the only stress/constituent not listed is woodfuel services—adequate energy. Not surprising, the mainly desert region of Kidal has all four threatened constituents of well-being, but only one stressed ecosystem service.

Given the almost uniform distribution of stresses and threats, it would be difficult to determine priorities for development efforts. In the case of Mali, though, other factors weigh in such as population density, which is particularly skewed to vegetative/climatic zones and serves as a guide to where useful gains could probably be made in the short term. The analysis also shows quite clearly the many trade-offs that occur from using the various ecosystem services in an unsustainable manner. For example, although rice production has decreased the level of stunted children, it has increased the problem of access to quality water because of pesticide and other agricultural

runoff into the water system. Moreover, the conversion of wetlands to rice farming has caused higher occurrences of floods (as witnessed in the Mopti Region) as well as reducing the capacity to provide a natural water filtration system. The sustainability of the present rice farming techniques will need to be assessed and modifications may need to be introduced to reduce the impacts it has on other ecosystem services as well as the food provision service itself.

The other main area for policy focus would lie in the domain of water regulation and finding ways to mitigate the impacts of droughts. One of the main factors causing drops in crop yields are droughts and the unreliability of rainfall. However, the internal water recharge rate indicates sufficient water availability. The main problem, therefore, seems to lie in the proper management and putting in place appropriate technologies and policy mechanisms to regulate the sustainable use of this water resource. Another major driver which will also need to be addressed is the high population growth rate and the pressures it puts on ecosystem services and the well-being of future generations.

Although all regions face many challenges, this analysis supports the option of starting in southern regions such as Sikasso, Mopti and Segou. These areas are endowed with many ecosystem services, are experiencing deterioration in many of these services, have high population densities and fairly high levels of poverty. A detailed integrated assessment addressing critical ecosystem services, their links with the constituents of well-being, the main drivers and possible intervention strategies in these regions may go a long way in helping Mali achieve its Millennium Development Goals.

Table 4. Ecosystem services stressed and constituents of human well-being threatened by region

Region	Total incidence of poverty	Ecosystem Service Stresses	Constituents Stressed
Gao	78.7%	Biodiversity loss Food production Water supply, purification and regulation	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood
Kayes	62.4%	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)	Adequately nourished Adequate and clean drinking water Earn a livelihood
Kidal	92.8%	Water supply, purification and regulation	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood
Koulikoro	59.5%	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)	Adequately nourished Adequate and clean drinking water Earn a livelihood
Mopti	76.2%	Biodiversity loss Food production Water supply, purification and regulation	Adequately nourished Adequate and clean drinking water Earn a livelihood
Segou	68.2%	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)	Adequately nourished Adequate and clean drinking water Earn a livelihood
Sikasso	65.8%	Biodiversity loss Food production Water supply, purification and regulation Fuel (energy)	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood
Tombouctou	76.8%	Biodiversity loss Food production Water supply, purification and regulation	Adequately nourished Adequate and clean drinking water Energy Earn a livelihood

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