Survival in the Sahel

An ecological and developmental challenge

Edited by
Klaus M. Leisinger and Karin Schmitt
and the
International Service for National Agricultural Research (ISNAR)

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Citation

Leisinger, K.M., Schmitt, K., and ISNAR (eds) 1995. *Survival in the Sahel.* The Hague: International Service for National Agricultural Research.

Original Title

Überleben im Sahel: eine ökologische und entwicklungspolitische Herausforderung / hrsg. von: Klaus M. Leisinger; Karin Schmitt. – Basel; Boston; Berlin: Birkhäuser, 1992. ISBN 3–7643–2710–3

AGROVOC Descriptors

agriculture; research; natural-resources; women; sustainability; Sahel; Mali

CABI Descriptors

agricultural research; natural resources; women; sustainability; Sahel; Mali

ISBN 92–9118–020–3

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Foreword

The seriousness of the environmental and socioeconomic crises in Africa has been the subject of numerous meetings, conferences, and publications. The case of the Sahel, plagued by civil strife, poverty, and hunger and natural calamities such as desertification and droughts, has become a major challenge facing humankind today. The environment and the living conditions have continued to deteriorate in spite of heavy investments, innumerable plans of action, and new organizations and institutions—a baffling puzzle, considering that worldwide our generation has experienced more technological breakthroughs than ever before.

It may seem to those interested in the development of the Sahel that there has been only bad news about the region over the past two decades. This has led some to believe that there have been no success stories. Obviously, in spite of the overall gloomy picture, there have been successes. The question is why these cases, rare though they may be, have not been reported and shared among the African countries and the international community.

Today's situation, the result of a combination of human behavior, poverty, illiteracy, rapid growth in populations, ecological phenomena, historical baggage, economic policies, and the political environment, is extremely complex. Consequently, there can be no simple solutions "borrowed" from elsewhere to resolve these problems. The solutions must come from within the region and must necessarily include some degree of trial and error. The challenge is how to avoid errors that may contribute to further deteriorating a situation that is already so precarious.

Survival in the Sahel presents no remedies for these ills; instead, it suggests alternative ways of dealing with the situation. It shows with practical examples and sound data how socioeconomic conditions and the environment continue to deteriorate because of the failure of past strategies. New approaches are

deemed to have a better chance of success if they have a long-term perspective, are based on small-scale actions, use a more holistic approach, take more account of women, and seek the full participation of local people. The results of such strategies may be small, but there *will* be results, and they are more feasible than the grandiose expectations of large-scale operations.

A detailed account of Mali illustrates the situations and problems that were discussed in the first part of the book. The case of Mali may seem at first to lead to a conclusion of hopelessness, but the positive results in the Cinzana region of Mali, reported by the CIBA-GEIGY Foundation for Cooperation with Developing Countries and the International Service for National Agricultural Research (ISNAR), present a more positive outlook. Based on the strategies discussed above, the CIBA-GEIGY experience shows that improving the well-being of the people of the Sahel in a sustainable manner is not a lost battle. This positive experience underscores the importance of agricultural research in correctly addressing the Sahelian situation and problems. Equally important, reporting this experience is a break from the tradition of circulating only bad news.

Several lessons and implications can be derived from the book. Among these, four predominate. The first relates to the need for solidarity from the international community in tackling the situation This is a need that comes not only from altruism, but also from the fact that if nothing is done to improve the situation in this one area, the global community as a whole will share the costs and eventually suffer.

The second lesson calls for revising present development strategies. Over the years, bilateral as well as multilateral donors have prepared many plans of action, but the question remains: To what extent have the new approaches described above been taken into account, and is there enough flexibility in these plans to incorporate them?

Third, the contribution of agricultural research to solving the problems of the Sahel, its people, and its natural environment cannot be ignored. Agricultural productivity must increase rapidly, but without further deterioration of the environment. That in itself is a challenge.

The fourth lesson is related to the CIBA-GEIGY Foundation's experience in Cinzana, which clearly shows that if the battle is to be won, there must be a place for actors who do not have development assistance as their primary *raison d'être*. Private-sector companies and foundations and nongovernmental organizations (NGOs) can make valuable contributions in many small ways. This is summarized by an ancient piece of African wisdom: "If many little people in many little places perform many little deeds, they can change the face of the earth."

Survival in the Sahel is the joint product of European, African, and American theorists and practitioners from a broad range of disciplines. Without this interdisciplinary collaboration it would not have been possible to illustrate how complex and interrelated the environmental and developmental problems of the Sahel really are.

The book grew out of the idea that there had to be a way to bring a seed-research development project in Cinzana, Mali, into a broader context. This would help illustrate the limitations of local efforts and the need for an integrated and collaborative approach to development.

The famines that have plagued the people of the Sahel during the last 25 years have deeply moved the world. Many people wish to understand the reasons for the immeasurable human suffering in the region. Indeed, there is an obligation to inform the public of the complexity not only of the problems but also of the solutions involving the environment and development in the Sahel.

For this reason, in spite of the somewhat scientific approach taken here, we have attempted to address readers who have no particular prior knowledge of the subject. *Survival in the Sahel* aims to present an easily understandable overview of the problems that confront the people of the Sahel. We do not claim to have treated the issue exhaustively or even sufficiently. For the sake of brevity, many important topics could be discussed only succinctly.

As we approach the end of the twentieth century, it becomes more clear that the conditions of development and the state of the environment will determine whether the human race will live in peace and greater justice in the future. One of the purposes

of this book is to encourage interested laypeople to become more concerned about these issues.

The original German version, *Überleben im Sahel*, was received enthusiastically when it was first published in 1992. In 1994 the CIBA-GEIGY Foundation and ISNAR decided to jointly produce an English-language version to bring the important issues discussed in the book to the attention of a wider audience. ISNAR updated the book where necessary and added a chapter on agricultural research in sub-Saharan Africa (Chapter 8).

Both the CIBA-GEIGY Foundation and ISNAR would like to express their sincere gratitude to a number of individuals who have been particularly helpful in writing this book.

We wish to thank Montague Yudelman, former Director of Agriculture and Rural Development at the World Bank, who kindly offered his 30 years' experience in rural and agricultural development in Africa and reviewed the Cinzana Research Station according to schedule. Ms. Gudrun Graichen-Drück, a political scientist, generously contributed a chapter on the situation of women in the Sahel (Chapter 7).

We are also grateful to Bruno Messerli of the Geographic Institute of the University of Berne (Switzerland), and his associates (Jürg Brand, Thomas Hofer, Susanne Wymann, Markus Wyss, and especially Daniel Maselli), who provided information on natural resources in the Sahel zone.

Oumar Niangado, director of the Cinzana Agricultural Research Station in Mali, has been primarily responsible for the success of the work carried out at the station. His input was very helpful in the preparation of this book. Felix Nicolier, who is responsible for the Cinzana project at the CIBA-GEIGY Foundation, offered constructive criticism during the preparation of the book.

Our thanks also go to Renate Gielen, an agricultural engineer and director of "Multiplication et diffusion des semences sélectionnées des espèces vivrière de culture sèche," a joint project of UNDP, FAO, and Mali's Ministry of Agriculture; and to Mariame Haidera, a nutrition expert at the Institut d'économie rurale (IER), in Bamako, Mali.

Dr. Hartmann P. Koechlin, honorary consul of Mali in Basel, provided information about political events in Mali and the initial development of the Cinzana Agricultural Research Station. Dr. Bernhard Gardi of the Museum of Ethnology in Basel contributed a historic and ethnic overview of the Sahel zone.

Dr. John F. Scheuring, a former seed specialist at the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), played a significant role in developing the Cinzana Agricultural Research Station. He has positively influenced the course of seed research in Mali, in both word and deed.

ISNAR acknowledges Peter Oram, from the International Food Policy Research Institute (IFPRI), for his work on the chapter on agricultural research in sub-Saharan Africa.

Finally, we want to express our gratitude to Theodore Wachs from the Geographic Institute of the University of Berne, Switzerland, for his excellent English translation.

Without all of the above individuals this publication would not have been possible.

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April 1995

Introduction

Introduction

In 1983 the Economic Commission for Africa published a report that offered an outlook of the African continent to the year 2008. The report stated that unless dramatic political, economic, and social improvements were introduced into the various countries, Africa can expect a nightmare of overpopulation, land shortages, poverty, and famine of unimaginable proportions.[1] The global situation has deteriorated considerably since 1983, and the Sahelian countries in particular are coming closer to making this catastrophic scenario a reality.

If anything, the Sahel zone of Africa graphically illustrates the deep human suffering rooted in poverty and the problems of development efforts. The people of the Sahelian countries—Burkina Faso, Chad, the Gambia, Mali, Mauritania, Niger, and Senegal—are faced with every type of problem that development programs are concerned with: poverty, hunger, disease, high population growth rates, environmental degradation, and an increasing shortage of natural resources.

Since the 1970s many people have associated the word Sahel with drought, famine, civil war, refugees, and poverty. Yet this has not always been so. For travelers in the Middle Ages the region was a "shore" (Arabic *sahil*) of rescue. Here, after crossing a "sea" of desert, they would find vegetation, water, and flourishing human settlements.

Three major droughts and their subsequent impacts have claimed millions of lives in the Sahel since the late 1960s, which has resulted in current the general perception that the Sahel is beset by hopeless and insoluble problems. An increasing number of people are no longer able to nourish themselves sufficiently on the land available to them, nor are they able to find enough work to earn a living. These factors leave them no other option but to abandon the Sahel.

In spite of modest efforts to improve food security, increase the standard of living, and create productive jobs, it appears that

the obstacles are becoming almost insuperable. But time for finding solutions is running out. Resignation or lack of action would cause only more human suffering and magnify the region's problems. High population growth rates and the encroaching environmental degradation are constantly eroding options for solving the problems. Moreover, it is becoming increasingly likely that developing-country refugees, driven by poverty and deteriorating environmental conditions, will become emigrants knocking at the door of the industrialized world; their survival problems may become domestic political problems for the developed world.

From this point of view appropriate help is not only a humanitarian duty, but also in the best interest of the industrialized world. Furthermore, the poor in the developing countries could be helped to preserve their dignity if they could secure their existence in their own countries. This is certainly to be preferred to condemning them to a life in the margins of the developed world, where they not only find an entirely different social environment but also often find themselves rejected.

But what is appropriate help? What kind of external support will help the people of the Sahel to decide to remain where they are?

Solutions to development problems in the Sahel must be sought within the countries concerned. External food aid only makes sense if it is used to avert or at least ameliorate acute famines. It must not be instituted permanently, because this would create new and equally serious problems. The challenge of development therefore lies in the search for environmentally sound, labor-intensive agricultural strategies that will increase productivity.

There are no large-scale solutions in terms of development blueprints that can be applied universally at any time. As with all other complex problems of our age, the road to success consists of many small steps in the right direction. An ancient piece of African wisdom puts it this way: "If many little people in many little places perform many little deeds, they can change the face of the earth."

There are many reasons for the misery that engulfs the people of the Sahel. Some lie in the colonial past, others are rooted

in traditional thought and behavior patterns. The major threads in this tapestry of problems are climate, a fragile ecosystem, destructive agricultural-production and animal-husbandry patterns, and a high population growth rate.

A survival strategy for the people of the Sahel must attack a multitude of problems and overcome many obstacles. Above all it requires the political will on the part of the governments of the countries in question.

The effectiveness of development cooperation (that is, providing external resources to support local efforts) depends on discussing with all parties concerned the nature of the problems and the relative merits of the proposed solutions. All social, economic, and ecological effects of the proposed package of measures must be examined in this deliberation process. If all participants in the process then cooperate reasonably in the execution of an agreed-upon project, it will stand a far better chance of success than one that is designed and implemented unilaterally.

The most suitable approach for solving problems at the local level can be found by identifying target groups and their specific needs and cooperating with them in a constructive manner, and combining modern methods and traditional knowledge. Any other approach runs the great risk that well-intended measures will get lost in the tangle of problems, and that action will be wasted in an unfruitful struggle and combat only the symptoms.

The poverty problem afflicting the people of the Sahel can be compared to a mosaic. Each stone in the mosaic has its particular significance and appearance and each one is important. But only together do the stones complete the picture. The same can be said of approaches to alleviating poverty. Dealing with a particular aspect is important and meaningful, but to solve the entire problem it is necessary to implement a range of measures simultaneously.

To ensure that economic and social development in the Sahel is adequate and sustainable, natural resources will have to be conserved rather than destroyed, hope will have to be stimulated rather than stifled, and every bit of progress, no matter how small it seems, will have to be nurtured with great care. Resigna-

tion is inappropriate, for progress *is* possible in the Sahel. *Survival in the Sahel* reports on this progress.

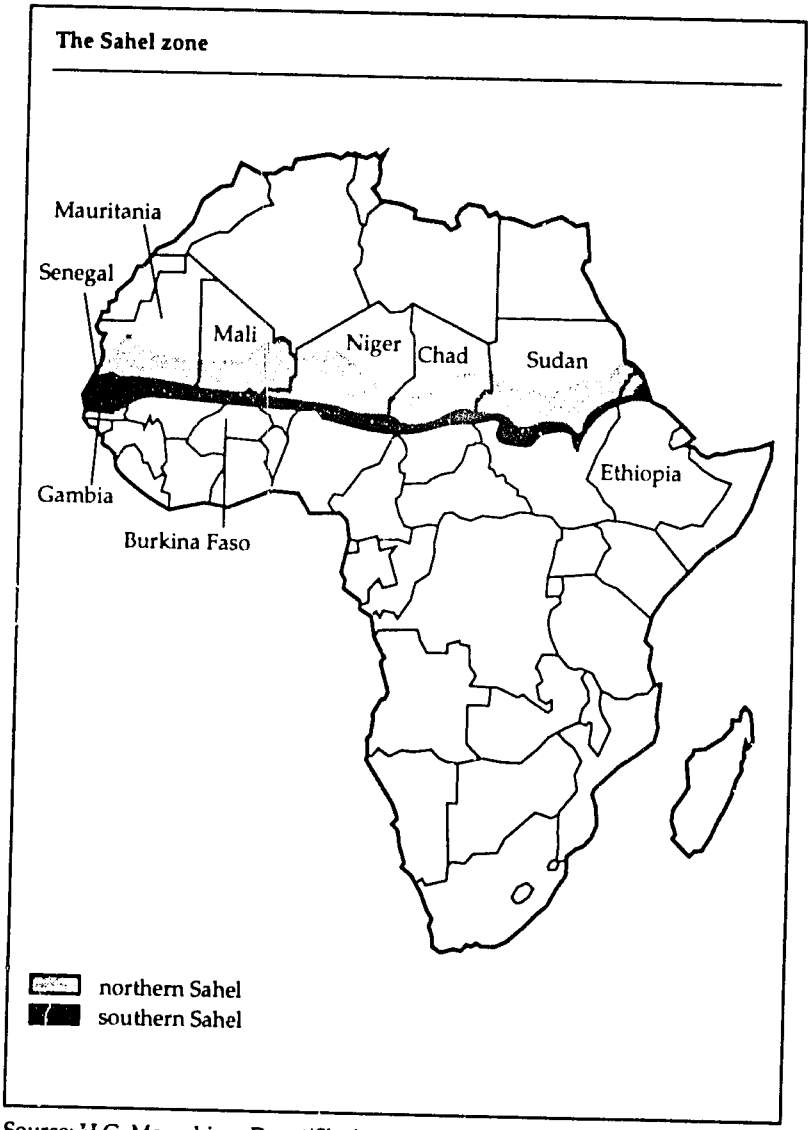
In Part I, the book discusses the living conditions in the Sahel and introduces its people. It then shows that in the past external development efforts often failed because they focused on what donor organizations and countries could do rather than what the recipients could absorb. Donors also depended too much on approaches that were technically too advanced and too resource-intensive. They also often neglected important segments of the target population, especially women, and they have generally underestimated the role that agricultural research can play in working toward greater food security. In Part II, the food problems that threaten the Sahel zone, as well as possible solutions to these problems, are illustrated in a detailed account of Mali and millet, the most important food crop in the region.

The example of a particular development project shows how initiatives operating under the motto "small is beautiful" slowly but gradually yield results that the target population feel they have produced on their own. This enables them to continue to work with the necessary motivation. This project is only one specific example in one particular environment. But it illustrates the long-term feasibility of interventions that utilize medium-level technology and that are financially sound and acceptable to their beneficiaries. At the same time they fulfill the conditions for sustainable development in a local environmental context.

Survival in the Sahel closes with an account of the lessons learned from CIBA-GEIGY's involvement in the Cinzana agricultural research station in Mali—the most important lesson for donors being that agricultural research requires a long-term commitment.

I The Sahel

Figure 1



Source: H.G. Mensching, *Desertifikation*. Darmstadt, 1990. p. 55

1 Geographic Outline

The Sahel is a geographic zone of about 5,000 km long and 300 km wide along the southern fringes of Africa's Sahara desert. Climate, agriculture, and ways of life are relatively uniform across national boundaries. The actual borders of this zone are usually defined not in political or geographic terms, but in terms of mean annual rainfall. In the north, where the Sahel merges with the Sahara, annual rainfall averages 200 mm. Along the southern border with the Sudanian zone the average is 600–700 mm (see Figure 1). The chief characteristic of the Sahel zone is that it is prone to frequent and lengthy periods of drought.

The Sahel is generally understood to comprise seven countries: (from east to west) Chad, Niger, Mali, Burkina Faso, Mauritania, Senegal, and the Gambia. They form a semi-arid transition zone from the southern Sahara to the savanna lands of west and central Africa. Their sizes vary greatly: Chad, Mali, and Niger have a total area of more than 1.2 million sq km each (the total combined area of united Germany, France, the United Kingdom, and Switzerland). Mauritania is approximately 1 million sq km. Burkina Faso, with 274,000 sq km, is somewhat larger than the former Federal Republic of Germany. Senegal is 197,000 sq km. The Gambia, the smallest country on the African mainland, is 11,000 sq km.

Regardless of size, the population of any country in the Sahel zone is smaller than that of greater London or Mexico City. In 1992, Burkina Faso had 9.5 million inhabitants, Mali 9.0 million, Niger 8.2 million, Senegal 7.8 million, Chad 6.0 million, Mauritania 2.1 million, and the Gambia 1 million, totalling almost 44 million.[2]

2 Historical Overview

The history of the Sahel is characterized by many types of encounters between people from a broad range of cultural backgrounds. Fair-skinned Berber- and Arabic-speaking peoples from north Africa and the Sahara and dark-skinned groups from further south came to this region, as did people with different agricultural production methods, including sedentary populations as well as nomads. They have engaged in trade, formed alliances, mixed with each other, or fought against each other. There has also always been great linguistic diversity in the Sahel.

The trade routes through the Sahara have been used since ancient times. Actually, the Sahara desert has bridged rather than separated societies from north and central Africa. Although relatively few people actually lived in the Sahara, those who did have claimed and controlled vast territories.

The final process of the gradual desiccation of the Sahara began around 2500 BC and must have triggered both northerly and southerly migration. Many of the groups who migrated to the south are assumed to have settled along the Senegal and Niger rivers and Lake Chad. There they intermixed with, or waged war against, people who had already settled there. Some may also have moved on further south. The camel (more precisely the dromedary) first appeared in the Sahara only a short time before the Christian era started. The Sahara had apparently become so dry that horses could no longer be used on large parts of it.

By about the year 1000, a pattern of ethnic dispersion had been established, similar to the one we know today. Sanhaja Berbers, the ancestors of the present-day Mauritanians, had settled in the west. In the central regions lived the Garamantes, from whom the Tuareg descended. Both groups had developed many ethnic subgroups. Not far to the south was the Kingdom of Ghana, ruled by the Soninke and in close contact with the Sanhaja Berbers and the Garamantes. The principal centers of ancient Ghana (Audaghost and Koumbi Saleh) are today part of the Mauritanian desert. Ghana (about 6th to 11th century AD) and the kingdoms

that succeeded it—Mali (13th to 16th century AD) and Songhai (c. 14th century to 1591)—earned a considerable part of their income from import and export taxes in the trans-Saharan trade.

The main link between the peoples of the Sahara and the Sahel was trade. North Africa exported mainly luxury goods, especially textiles and also copper and silver, to the south. Exports from the Sahel went to Sijilmasa (present-day Tafilalt in southern Morocco). The main export item was gold, followed by slaves, pepper (malanguetta from Guinea, which later became known as the pepper coast), ostrich feathers, ivory, indigo, leather, and beeswax.

Salt has always been important in the Sahel's internal trade. A family of five uses about 10 kilograms of salt per year, and 10 camels need 50 kilograms. Salt was mined in, for example, Idjil (Mauritania), Taodeni (Mali), Fachi, and Bilma (Niger). While salt came from the southern Sahara, gold was mined in Bambuk and Bure in the geographic triangle formed by Mali, Senegal, and Guinea.

Trade was possible because the hinterland of the western Sudan produced a sufficient number of goods. Probably even more important was that this hinterland had water. The Niger has played a particularly important role not only in the region but also throughout west Africa. Pearl millet (*Pennisetum*) was probably first bred in the vicinity of the great bend of the Niger. Cultivated plants such as cotton and indigo were first planted here thousands of years ago (earlier than in Europe), and rice was also produced at this time. There was an abundant supply of fish. Milk and meat from the many zebu, sheep, and goat herds of the livestock-breeding Peul formed an additional source of protein. It is certainly no coincidence that two ancient trading cities, Timbuktu and Djenné, the oldest known city in sub-Saharan Africa, were located along the Niger.

Trade has always meant much more than just the transport of goods from one place to another. Even in those days, it involved the exchange of ideas and people. It also meant an early spread of Islam to the region, which converted many of the upper class. The social structure established by Islam transcended ethnic boundaries and could thus support political structures.

Trade also demanded a division of labor. Throughout the Sahel and in neighboring areas of the Sudan, it was normal to own humans. Grouped together in separate villages, slaves, serfs, or bondsmen grew grain so that their "masters" could devote themselves to trade or warfare, which was regarded as a noble art.

These slaves were indeed the most important production factor in the Sahel until the beginning of this century. Their ancestors were non-Islamic ethnic groups in the more southerly regions, in particular the Bambara, the Bobo, the Dogon (all from Mali), and the Mossi and the Gourmantche (from Burkina Faso). They were usually kidnapped by troops on horseback. The horse (or in the case of the Tuareg, the camel) was a fearsome weapon when used against sedentary farming populations. This influenced horse prices considerably; a good horse cost the equivalent of five to 10 slaves.

Kidnapping was carefully timed. Raids were carried out during the dry season (April–May) so that newly abducted slaves could be used to plant millet at the start of the next rainy season (June–July). Following the harvest (October–November) some of the slaves, usually those who were ill or rebellious, were sold. Slave owners thus profited not only at harvest time, but also generated additional income in the form of gold, horses, or garments.

"Slave" is a complex term. The fate of a slave depended on the era and the region. There were times when more than 75 percent of the population lived in slavery. Although they enjoyed considerable freedom, slaves were permanently liable for high taxes, which had to be paid in the form of natural produce. In western Sudan distinctions were made among the first, second, and third generations of slaves. A son born to a female slave and fathered by her master had the status of a free man.

It would be wrong to assume that only the fair-skinned held dark-skinned people in bondage. Slavery also existed among dark-skinned peoples. The Tuareg, for example, kept household slaves. They also controlled many villages that were forced to provide the Tuareg with grain. Noble families among the Soninke, the Peul, the Bambara, and the Bozo in Mali, the Wolof and the

Tukulor in Senegal, and the Zarma and the Hausa in Niger, also possessed slaves. These were used for hard labor.

With the increased presence of Europeans on the west African coast, the trans-Saharan trade lost in importance. As early as 1600, European sailing vessels could carry more than 200 tons of merchandise. A caravan of 1,000 camels could transport not more than 100 tons. By the beginning of the 20th century, the caravan trade between north and central Africa had been brought to an almost complete standstill. Because transport costs were low for the Europeans, the movement of goods was reversed into a southerly direction. The result was a dramatic drop in income for nomads and an economic decline of the kingdoms of western Sudan, whose trade centers in the Sahel had been oriented toward the north.

By 1900, France completed its occupation of Senegal, Mauritania, Mali, and Niger, the area known as Afrique Occidentale Française (French West Africa). Administrative regulations brought about far-reaching changes in the following decades. The forced termination of tribal feuds was certainly one of the most significant. After internal wars and conflicts had been ended, slavery was abolished in 1908. Silver was also introduced around this time. Initially hoarded and used to make jewelry, it later served as the basis of a cash economy that integrated the entire population.

3 Population

3.1 Demographic development

In 1980–92, the population of the Sahel grew at an annual rate of 2.8 percent (see Tables 1a and 1b). If the population continues to grow at this rate, it will double in about 23 years.

The main reasons for the high population growth rate in the Sahel are the sharp decline in mortality rates in the last 40 years and birthrates that have either stabilized or shown occasional increases.

The decline in mortality was achieved in a relatively short period, mainly because hygienic and sanitary conditions have improved, basic healthcare programs have been introduced, vaccination (especially of children) has spread, and oral rehydration remedies and basic drugs (in particular antibiotics) have become more widely available. Large-scale food aid programs have kept many people from starving during periods of poor harvests, which contributed to a drop in mortality.

Birthrates in the Sahel, as almost everywhere in developing countries, are greatly influenced by cultural and social factors and traditional patterns of thought and behavior. Birthrates change much more slowly than mortality rates.[3] The decline in mortality, combined with stable, high birthrates, has produced a very youthful population structure. In most Sahelian countries more than 45 percent of the population is under the age of 15.[4] This means that almost half of the people currently living in the Sahel still has to reach reproductive age. This means that even if birthrates were to drop sharply in the short term—which is unlikely—the population would still almost double in the coming years. The number of young women who will reach reproductive age is so large that a drop in the number of births per woman will make little difference.[5] The prospect of continuing high population growth rates has very serious economic, social, and ecological implications for the people of the Sahel.

Table 1a

Population growth in the Sahel

Country	Population in 1991 (millions)[a]	Total population growth ('000) (1991–92)[a]	Average annual population growth rate (%; 1980–92)[b]
Gambia	1.0	31	3.8
Niger	8.2	258	3.3
Senegal	7.8	217	2.9
Burkina Faso	9.5	271	2.7
Mali	9.0	255	2.6
Mauritania	2.1	55	2.5
Chad	6.0	151	2.4
Sahel zone	43.6	1,021	2.8

Sources:
[a] World Bank, *Social Indicators of Wealth 1994*, (on diskette), Washington, D.C. 1994
[b] World Bank, *World Tables 1994*, (on diskette), Washington, D.C. 1994

Table 1b

Population growth rates (%; 1980–92)

World	All developing countries	sub-Saharan Africa	Sahel zone
1.7	2.1	3.2	2.8

Source: World Bank, *World Development Report 1994*. Washington, D.C. 1994. Table 25, p.210 ff.

3.2 Population density

Population density, measured by number of inhabitants per sq km, is low in the Sahel. The Gambia has 85 people per sq km (by comparison, Germany has 223 people per sq km). Senegal has 38, Burkina Faso 34, and the remaining four have an average of less than seven people per sq km.

However, only a small portion of the total land area of the Sahel is suitable for ecologically and economically sound agriculture. The ratio of inhabitants to available agricultural land thus presents a much darker picture than the low population density might suggest. The highest population densities relative to cultivable land are 633 people per sq km in Mauritania, 293 in Mali, and 228 in Burkina Faso. In Senegal the rate is lowest at less than 100 people per sq km.[6]

Population growth reduces the number of human habitats with fertile soils, because the pressure on natural resources is becoming greater than nature can handle in the long term. Since traditional natural regulating mechanisms are no longer in effect, a process of environmental degradation has been set in motion that is continuing under its own momentum.

In the past, life in rural Sahelian societies was self-regulatory, governed by the relationships to the natural environment. Today, however, rural life is increasingly being shaped by the impact of a disturbed ecological equilibrium.

3.3 Employment structure

Agriculture is the most important economic sector in all Sahelian countries. In Burkina Faso, Chad, Mali, and Niger agriculture accounts for more than 35 percent of gross domestic product (GDP). In Mauritania and the Gambia it is almost 30 percent and in Senegal 19.[7]

The majority of the population in the Sahel—from 50 percent in Mauritania to 83 percent in Burkina Faso (1992)—lives in rural areas. They depend on agriculture for their livelihood.[8] Because productivity is low and unemployment widespread, most people in rural areas earn very low incomes, if at all; virtually the entire rural population lives at or below the poverty line.

The living conditions in Sahel's rural areas have changed little since the 19th century. Belonging to a particular kinship group and age group, and the status this entails, continue to have an overriding importance. Although slavery no longer exists in its original form, traditional hierarchies and a complex network

of relationships and obligations that bind kinship groups together determine daily life in rural societies. In most cases the older generation, and the heads of families in particular, exercise fairly strict control over younger members of the extended family and the group. They arrange marriages, set the bride price, determine the number of children, and control many economic factors.[9]

Small family farms, employing time-honored production methods, account for most agricultural output. Small farmers depend primarily on the natural fertility of cultivable land and on traditional tools for their subsistence. With few exceptions, such as the use of donkeys in parts of Burkina Faso and ox-drawn implements in Senegal, the main source of energy is human labor, very often women. Only in rare cases are purchased inputs (such as seeds, chemical fertilizer, plant-protection products, and more sophisticated tools) used to increase productivity. This has a very negative long-term impact on rural income.

Although rigid social structures have remained largely intact, the social order in rural areas is being undermined by the increasingly smaller area fit for living. The social order is also being eroded by greater rural poverty and an exodus of the younger members of the rural population to urban areas.

3.4 Urbanization

In the Sahel, as in other parts of sub-Saharan Africa, rural poverty and high population growth rates are accompanied by rapid urbanization (see Table 2).

One reason for the high urban growth rates is the consistently high birthrates in urban areas, which are virtually as high as those in rural areas. Another reason is that droughts over the last 25 years have had a destructive effect on croplands, destabilizing rural societies. Many people, especially the young, have abandoned their family homes and migrated to urban areas to escape from famines and the effects of environmental deterioration. They hope cities will create new opportunities, ensure survival and social advancement, and provide proper education for their children.

Table 2

Urbanization in the Sahel (in %)

Country	Urban population as % of total (1992)	Annual population growth rates 1980–92	
		Total	Urban
Burkina Faso	16.9	2.7	8.7
Niger	20.9	3.3	7.4
Mauritania	49.6	2.5	7.2
Chad	33.8	2.4	6.8
Gambia	23.8	3.8	6.1
Mali	25.1	2.6	5.2
Senegal	40.8	2.9	4.0
Average Sahel	30.1	2.8	6.0

Sources: World Bank, *Social Indicators of Wealth 1994.* (on diskette), Washington, D.C. 1994; and World Bank, *World Tables 1994.* (on diskette), Washington, D.C. 1994

Young people also often move to urban areas to escape from the rigid social structure of traditional rural life. Once settled in the city they no longer feel the pressure and influence of the extended family and the village, and traditional values start losing importance. The search for new values begins.

Prior to the revolutionary changes in eastern Europe, the younger generation was especially attracted to various forms of socialism. In recent years, however, Islam—often in its fundamentalist form—has had a growing appeal. Not least among the reasons for this has been disappointment with the Western development model, which is associated with colonialism and missionary activities and has failed to bring about changes for the better.

But most of those who migrate from rural areas end up in slums. City authorities do not have the resources to invest adequately into housing, streets, drinking water, and sewage disposal to meet the demand by the rapidly growing urban populations. Experience has shown that very few who seek their fortune in the city achieve what they have dreamed of and hoped

for. Only a small minority of the well-educated young are able to make the transition to modern economic sectors. Most are either unable to find work or employed in the informal sector, where they earn no more than subsistence wages. They use polluted water for drinking and washing; only the privileged few can afford imported bottled water. While the wealthy, dressed according to the latest western fashion, have their chauffeurs drive them to luxurious restaurants and hotels, most of those who have fled the countryside dress in rags, eking out a miserable living in cardboard huts in urban slums.

In terms of quality of life, it is hard to see any significant difference between people living in absolute rural poverty and those languishing in city slums. Hopelessness and despair, as well as the awareness that there is only the slimmest chance of success in terms of the values and goals of the upper classes, are immensely tragic consequences of underdevelopment. What makes a life of poverty in the city even more unbearable is the direct, day-to-day confrontation with the often staggering wealth of a tiny minority. This contrast constitutes a frequently underestimated threat to sustainable and peaceful development in developing countries.

3.5 Economic and social development

With the exception of Senegal, all Sahelian countries are classified as so-called least developed countries (the countries with the poorest economic and social conditions in the world). All are found in the lowest regions in the Human Development Index, with two of them in the last two spots and the rest among the last 16. (Ranking 173 countries, the Index is a composite measure of human development containing indicators representing three equally weighted dimensions of human development: life expectancy at birth, adult literacy and mean years of schooling, and purchasing power.[11]) The indicators in Table 3 illustrate their low level of economic and social development.

The living conditions in the area are characterized by an inability to satisfy basic needs. Minimum individual nutritional

Table 3

Economic and social development in the Sahel

Country	GDP per capita[a]	Life expectancy[b]	Infant mortality rate[c]	Adult illiteracy[d]
Senegal	801	49	68	62
Mauritania	520	48	117	66
Mali	298	48	130	68
Gambia	298	45	132	73
Burkina Faso	292	48	132	82
Niger	281	46	123	72
Chad	209	47	122	70

[a] In US $ (1992). GDP at factor costs. Only for Senegal GDP at market costs.
[b] At birth, in years (1992).
[c] Per 1,000 live births (1992).
[d] Percentage of adults of the total population (1990).

Source: World Bank, *World Tables 1994*, (on diskette), Washington, D.C. 1994
Percentage of illiterate adults from World Bank, *Social Indicators of Development 1994*, (on diskette), Washington, D.C. 1994.

needs and shelter are not guaranteed, and the state cannot provide a minimum of vital government services, such as safe drinking water supplies, sanitation, health care, and educational facilities. Nutritional deficits, illustrated in particular by hunger and malnutrition, have a catastrophic impact on the quality of life as well as on people's health.

According to UNDP data, the daily calorie supply for inhabitants of the Sahel seems to have improved somewhat. In the period 1984–86, the calorie supply in all the Sahelian countries was well below the minimum set by the World Health Organization (WHO). In 1988–92 only Chad remains significantly below the limit with 69 percent of what is required. The calorie supply for the other countries ranges between 95 and 109 percent.[12]

4 Agricultural Production

Millet and sorghum are among the major food crops in the Sahel, accounting for 50–70 percent of the cultivable land planted with crops. Groundnuts and cotton are the most important cash crops grown for export. Groundnuts are grown mainly in Senegal and Gambia, while cotton is the main export crop of Mali, Chad, and Burkina Faso. Although cotton is planted on only a small percentage of the cultivable land, it accounts for 60–80 percent of foreign-exchange earnings because of its high value. Livestock husbandry is an important source of income for about one-quarter of the population.

4.1 Developments in food production since 1960

Sahelian countries were largely self-sufficient in food production until the 1960s. In 1961–92, however, food production in the Sahel rose by only 1.8 percent per year, far less than the annual population growth rate. In 1988, a year with abundant rainfall, almost all Sahelian countries enjoyed a record harvest. But by 1990 harvests were five percent down from 1989 and 15 percent down from 1988.[13]

In the Sahel, food production has always depended to a large extent on climatic factors. But the remarkable success in food production in Niger, for example, has made it clear that political factors such as price policy, extension services, credits, and other means of support to small-scale farmers can intensify or significantly cushion the impact of adverse climatic factors.

To avoid dramatic food shortages in the Sahel, it has been necessary to compensate the decline in per capita food production by increasing food imports, in particular cereals. Cereal imports, supplemented by extensive food aid, rose from about 200,000 tons at the beginning of the 1960s to over 1.3 million tons in the early 1980s.[14] In 1988, in spite of sufficient rainfall, an even greater amount—1.9 million tons—was imported. This is an eightfold

increase in food imports in 30 years. What had once been necessary only during extreme droughts and other emergencies to fend off disastrous famines and save human lives became permanent with time. Today, even in "normal" times, 15–20 percent of the region's food supply is imported.

In terms of development, this is pointless. Food aid that is not properly administered or that is instituted over the long term independent of acute shortages can have serious consequences. An external supply depresses the price of locally produced food and thus deprives farmers of an incentive to produce surpluses beyond what they need for home consumption. In addition, since industrialized countries often donate their own food surpluses, food aid may not be adapted to local dietary preferences of the recipient countries. Consumption of imported foods may therefore lead to a drop in demand for indigenous crops in the long term (such as a gradual preference for wheat instead of millet).

Donated surpluses are often valued highly by governments in recipient countries because they can be sold, providing an important source of income for the government and supply for privileged target groups, such as the army. Thus food aid can be a seductive poison; adapting it can result in a decline in the local food supply.

4.2 Socioeconomic limiting factors in the development of agriculture

Sahelian countries face enormous obstacles to development. The slow development of agriculture in the Sahel, and hence in food production in the region, is due not only to climatic variation[15] and poor soil quality, but also to poor economic, political, and social conditions. Men and women engaged in small-scale farming have almost no access to training and agricultural extension services that would address their problems. Nor do they have any chance to acquire much-needed credits for purchasing inputs to increase production, such as chemical fertilizer, seed, and agricultural implements.

Improved seed varieties, fertilizers, and plant protection products are part of a "technological package" used almost exclusively for export crops such as cotton and groundnuts. The total amount of chemical fertilizer used in Sahelian countries is less than half of the already low average for sub-Saharan Africa. Past production increases have been achieved usually by expanding the land under cultivation and only rarely by increasing yields.[16] Less than one percent of the land under permanent cultivation is irrigated. Large-scale irrigation systems are extremely rare, because they are much too expensive.

Moreover, there is no incentive for farmers to increase production because the chances of selling their produce on the market are poor. In countries where the majority of the population is engaged in agriculture or livestock husbandry, the remaining population does not generate sufficient demand to constitute a market for agricultural products, especially when the government has set very low prices. Food imports and food aid further aggravate the situation. Export production, introduced in colonial times, continues to have a much higher priority than cultivation of food crops for home consumption. Resources for providing extension services, fertilizer, and mechanization are rarely allocated to farmers who grow food crops. In some cases farmers are side-tracked to areas where production conditions are even less favorable.

Sustainable economic and social development will be possible in the Sahel—and in most mainly agricultural developing countries—only if rural development is sufficiently accelerated and agriculture becomes considerably more productive. Only if per capita production increases by about four percent annually is there a chance that the region will become self-sufficient in food production in the long term. Sahelian countries today not only face the challenge of having to increase their agricultural productivity under conditions of overall resource scarcity, they must also increase productivity in a way that will conserve the natural resource base, which has been damaged considerably in the last 25 years. The situation has been made even more difficult by population pressure and to some extent by debt service, with the

result that already scarce resources must be increasingly exploited.

The Sahel zone is at a great disadvantage in ecological terms. In the following pages, we shall examine the many ways in which ecological disadvantages make life and economic conditions so difficult, and also see why nature reacts so sensitively to human intervention in this region. This will make clear how climate affects nature as well as use of the environment by humans.

5 Climate and Natural Resources

5.1 Climate

While temperate zones have sufficient rainfall to support agriculture throughout the year, the situation in the Sahel, with its tropical semi-arid climate, is very different. There are no noticeable seasons that can be defined by temperature. Differences in temperature are more likely to occur between day and night and between lowland and highland areas than between summer and winter. The three- to four-month rainy season occurs during the summer from June to September, with rainfall ranging between 200 and 600 mm. Because of intense solar radiation and high temperatures, however, much of this precipitation evaporates before it can be used for agriculture. There is sufficient humidity for agriculture for only two to four months during the year, with dry months predominating the rest of the time.

The Sahel's climate is greatly influenced by global wind circulation patterns, which determine periods of rain and aridity in the region. It is worthwhile taking a brief, closer look at this process because it plays such a decisive role in the Sahel.[17]

Precipitation in the intertropical convergence zone (ITC)[18] has a major influence on the region's climate. Trade winds in the equatorial latitudes converge toward this zone. The zone itself migrates northward and southward with the seasons. A belt of moist air follows the ITC's movement. Precipitation in the convergence zone can fall at the equator in all seasons. A period of summer precipitation occurs in distant tropical zones, but in the desert the climate is continually arid.

In winter the Sahel is subject to the influence of the northeast trade winds, which are hot and dry as a result of their long journey over the desert. Precipitation is rare. The dry season grows longer toward the northern part of the Sahel.

At the height of summer the sun is vertically overhead at the northern tropic in the middle of the Sahara. Following the sun with a certain time lag, the ITC migrates north to about the 15th or 16th northern latitude, the areas north of the Sahel. This causes winds from the southwest to converge toward the Sahel. These winds absorb humidity over tropical waters in the Gulf of Guinea, and, as they move to the northeast, they bring long-awaited rain to the Sahel.

But even more critical for agriculture than the actual amount of rainfall or change of seasons is rainfall variability. The ITC moves irregularly, thus making precipitation variable. Annual variations of up to 50 percent can occur, depending on how far this zone of converging air masses advances to the north.[19] Rainfall becomes less certain toward the Sahara. In European latitudes, a year with 100 mm less precipitation than normal will hardly affect harvests. But in the Sahel, a drop of this magnitude puts the amount of rainfall below the 500 mm minimum necessary for rainfed agriculture, causing harvests to fail.

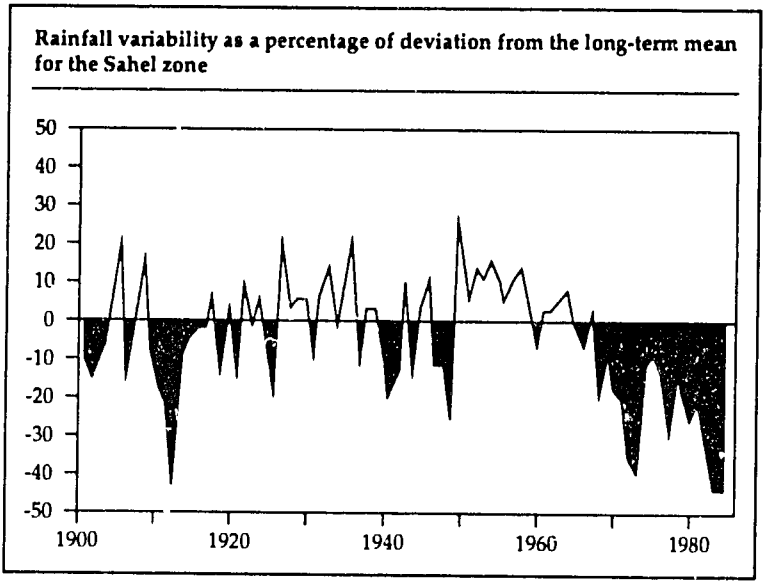
Figure 2 shows rainfall variability in the Sahel from the start of this century. It illustrates that years of above-average and below-average rainfall tend to come in clusters. If several dry years occur consecutively, food supply problems increase dramatically. The people of the Sahel can survive one year of failed harvest without major supply problems, provided that reserves are sufficient. But they cannot survive several consecutive years of harvest failure, such as during the long drought from 1968–73.

Climatic history and its present-day effects

Like all the earth's regions, the Sahel has been subjected to repeated climatic fluctuations throughout its history. Cold and warm and dry and moist periods have altered the face of the region many times. Figure 3 illustrates the fluctuations that have taken place over the last 18,000 years.

Approximately 20,000 years ago the Sahara expanded south-ward into the current Sahel zone during a pronounced dry period. Rivers dried up, vegetation died out, and sand dunes were formed. About 15,000 years ago climatic conditions began to

Figure 2

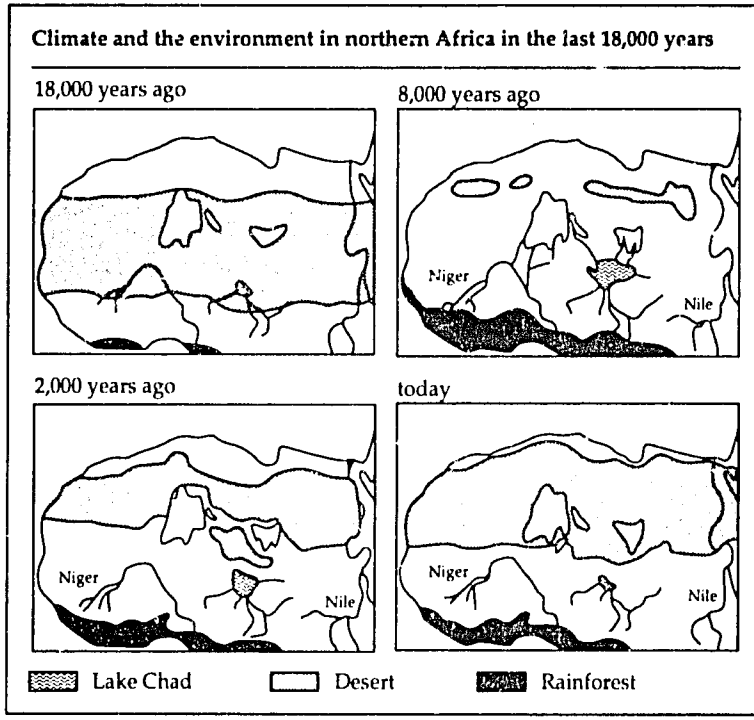


Source: UNESCO 1984, Brown and Wolf 1985

improve. Moist tropical air masses advanced far to the north during the summer months, bringing a considerable increase in rainfall.

This favorable climate lasted for about 5,000 years (about 8000–3000 BC). The Sahara desert receded to small, isolated areas in northern Africa. An enormous drainage network came into existence in the regions south of the Sahara. Lake Chad was much larger then than it is today. Rivers deposited sediments over broad areas such as the inland delta of the Niger, where land use today is based on extensive irrigation. Previously arid, desolate areas came to life again, and the tropical rain forest advanced far to the north. Sand dunes were gradually covered with vegetation and sand masses no longer migrated southward. Red, fertile tropical soils were formed in areas where it is virtually impossible for soils to be formed today due to aridity. Humankind is still

Figure 3



Source: B. Messerli, Geographic Institute of the University of Berne, Switzerland

profiting today from the favorable climatic conditions of that time; soils that were formed then continue to benefit present-day agriculture.

After this relatively "wet" period, the climate once again worsened. Precipitation became highly variable and the amount of rainfall dropped considerably, causing lakes, river systems, and rain forests to recede and leading to a renewed advance of the desert. Today climatic history still determines to a considerable extent the potential for agriculture in the Sahel. In many areas, people live in an environment that took many thousands

of years to develop. If these areas continue to be degraded, they will probably not recover under today's arid conditions.

Drought and famine in the Sahel

Many scientists believe that drought has always been a fact of life in the Sahel.[20] According to the American National Research Council, there were 12- to 15-year droughts in the 1680s, the 1750s, the 1820s and the 1830s.[21] In this century the Sahel has been plagued by extended droughts in 1910–14, around 1930, and in 1940–44, 1968–73, and 1980–84.[22] While there are indications that earlier droughts were confined to relatively small areas, there has been a continual increase in the duration and the extent of drought over the last 100 years and consequently in the destruction caused by it. This has held true up to very recent times.

The exceptional drought of 1968–73 affected no less than 16 countries (Cape Verde Islands, Senegal, the Gambia, Mali, Mauritania, Burkina Faso, Chad, Niger, Benin, Nigeria, the Central African Republic, Libya, the Sudan, Somalia, Djibouti, and Ethiopia). Another 14 nations in central and southern Africa were exposed to the 1980–82 drought.[23] These droughts caused untold human suffering, weakened the ecological equilibrium, and had a disastrous effect on agriculture and livestock production, with consequences that are apparent even today.

In each case the economic damage was immense and resulted in widespread impoverishment. For example, the exceptional 1968–73 drought, with rainfall deficits of 15–40 percent, caused grain harvests to fall by 600,000 tons, a 15-percent loss of the average annual yield. Agriculture and livestock production collapsed. Nomadic herders were no longer able to migrate to the Sudanian zone because it was already too densely settled. They were forced to exchange their last animals for millet or for the right to use a well. Hundreds of thousands of people died of starvation—200,000 in Ethiopia alone—and more than 80 percent of the livestock in the Sahel perished.[24]

The 1980–84 drought was the third in 10 years. In 1984 Gao, in the eastern part of Mali, received only 60 mm of rain, less than

half of what it had been in 1983, when it was already low. In a normal year this region receives 250-300 mm. One-third of Mali's population—seven million at the time—suffered from the effects until the mid-1980s, and five percent were threatened with starvation. The shortage of grain was estimated at 300,000 tons (based on a requirement of 180 kg per person annually). Animal herds in many regions were decimated, livestock prices dropped, and grain prices skyrocketed.[25]

There are many reasons for the dramatic increase in drought-related problems. One is that due to declining export earnings and the rising cost of imports the Sahelian countries are in difficult economic times, with less financial resources available to tackle their problems.[26] Human factors that have played a role in worsening the problems are high population growth rates, inadequate use of scarce soil and water resources, and inappropriate political priorities, including the inability of governments in most Sahelian countries to take timely and appropriate precautionary measures to prepare for the possible recurrence of drought.

5.2 Water

Water availability is directly related to climatic conditions. Throughout the Sahel sparse and unpredictable rainfall, rapid evaporation, and the low storage capacity of soils limit the amount of water available. Scarcity increases sharply toward the north. The situation is somewhat better in the regions traversed by large water courses, in particular the catchment areas of the Senegal River, the Niger River, and, further east, the Nile. Because these rivers all rise in the more humid southern part of the Sahel, they carry water throughout the year.

Procuring water is a fundamental problem in the daily lives of the Sahel's inhabitants. In the past, the main source was groundwater, which is replenished by rainwater. But with today's erratic rainfall, motor-driven pumps have often to be used to draw up water from deep wells. This is often fossil water, which means that it is not replenished by precipitation or river water. A

study in Senegal showed that water at this level was formed before the last ice age and can be up to 30,000 years old.

Although rapid population growth and intensified agriculture make it necessary to tap additional water sources, non-renewable resources must not be put at risk. Tapping fossil groundwater reserves could result in overuse and exhaustion of an indispensable, non-renewable resource. Gearing agricultural development efforts to the use of fossil water is therefore not a wise approach for the future.

5.3 Soils

Soils in tropical countries have many unfavorable characteristics. Their natural fertility and water-retaining capacity is low, and they are highly susceptible to wind and water erosion.[27] Soils in the Sahel have a low natural yield potential, due to poor nutrient fixation and a shortage of minerals that contain nutrients. In the past, traditional tillage methods, including fallow periods that often lasted for decades, compensated for soil vulnerability. Today, traditional methods are too unproductive to meet the food requirements of the rapidly growing populations.

Intensive cultivation in the Sahel requires high inputs of fertilizer and special fertilization techniques, as well as small but frequent doses of irrigation to avoid water loss through filtration and evaporation. In addition, it is necessary to ensure that damage to the topsoil is minimized at every step in the tillage process (clearing, plowing, and harvesting). Green manuring, crop rotation with legumes, and appropriate, combined agroforestry, implemented in accordance with traditional cultivation methods, are now recognized as the most suitable tillage techniques for fragile biotopes.[28] The first step in combating erosion, especially wind erosion, is to protect existing hedgerows and shrubs. Other steps include replantation of hedgerows and shrubs, no till or minimum till agriculture, and, where necessary, stabilization of sand dunes.

5.4 Vegetation

As precipitation increases south of the Sahara toward the equator, biological diversity becomes greater and vegetation denser. This results in different vegetation zones from Mauritania to Chad. The dry vegetation of the Sahel constitutes a fluid transition zone between desert to the north and savanna to the south. Thorny bushes and isolated low trees mark the pale-brown landscape, which is green only for a short period of time when there is sufficient rainfall.

Because rainfall is low and variable, plants have developed various strategies for the most economical use of the water. Annual plants survive dry spells in the form of extremely resistant seeds that retain their germinating ability for decades. After sufficient rainfall they grow, blossom, and bear fruit within a short time, temporarily covering normally barren areas with colorful vegetation. Dense hairs, an insulating waxy surface, or a thick, leathery "external skin" on the leaves reduce evapotranspiration. In extreme cases leaves transform into thorns or are shed completely during dry periods. Trees and shrubs have deep and extensive root networks, and herbaceous plants have tap roots several meters long, enabling them to penetrate into deep, remote water sources. Fleshy leaves and stalks, as well as roots and stems, can often absorb water during the rainy season and store it for use during dry periods.

Plants in the Sahel usually combine several of these strategies, rarely relying on only one of them. The various adaptation mechanisms of vegetation in the Sahel illustrate how narrow the confines of life are in a semi-arid region.

Trees—an endangered symbol of life

Trees play an essential role in the Sahel: they provide fuel, timber, and food, conserve the soil, and serve as windbreaks. They are a source of fertilizer and are used as medicinal plants. Due to population growth and a sharp rise in the demand for energy, the need for wood is increasing much more rapidly than reforestation

can supply. This overuse may cause an ecological catastrophe of indescribable proportions.

A German federal enquiry commission concerned with the environment, "Vorsorge zum Schutz der Erdatmosphäre," has called attention to the urgency of the medium- and long-term problems caused by excessive deforestation. The commission concluded that a firewood crisis is imminent.[29]

The proportion of wood in relation to total energy sources is very high in all Sahelian countries, reaching 96 percent in Burkina Faso. Procurement of firewood, mainly for heating and cooking, is the primary cause of forest destruction in the densely populated areas. Shortages are now so acute in most Sahelian countries that it is impossible for these countries to meet their firewood needs, even if they continued to overuse forest resources and burning agricultural waste products (instead of using the latter as fertilizer or livestock feed). In 1980 more than 50 million people in Africa were unable to meet their minimum firewood needs without overusing forests. Worldwide, some 130 million people will soon face similar problems.[30]

The firewood shortage has various serious economic, social, and ecological consequences, which, together, expand already widespread poverty:

- Great expenditures in time and labor, particularly from women and children, are required to collect firewood. This takes time away from other important activities, such as school attendance by children.
- Clearing trees and shrubs promotes wind and water erosion. This accelerates deterioration of the soil and causes agricultural production to decline, which in turn triggers a further rural exodus.
- In cities, where firewood usually has to be purchased, a larger portion of the family income must be spent on energy. This puts a heavy strain on the usually small household budget.
- City dwellers usually use charcoal rather than firewood. Current charcoal manufacturing processes cause a 50-percent loss in the original caloric value of wood.

Overuse of the remaining forest and shrub stands cause further economic, social, and ecological deterioration, and new vicious circles of underdevelopment come into play. Western countries frown upon women gathering firewood, threatening the last remaining forest stands. But this is highly inappropriate when we realize who has really been responsible for exploiting and destroying forests in the past decades—usually without the pressure of having to endure a day-to-day struggle for survival. Forest degradation has occurred at the hands of foreign companies and loggers, indigenous charcoal producers, and farmers and pastoralists penetrating into new areas. Not least among them are national and international agricultural experts, who designed projects that required irrigation on a large scale for the production of export crops such as cotton.

6 Environmental Degradation

6.1 Preservation of the environment as a human right

Toward the end of the 1960s the term "human rights of the third dimension" entered into the ecological and political discourse. It was used to describe rights that take precedence over the rights that protect the individual from the power of the state (first-dimension rights) and over individual economic and social rights (second-dimension rights). The right to peace, to human development, to environmental protection, and to preservation of our common human heritage—to mention only the most important rights of the third dimension—are more than merely individual human rights. They are rights of societies and nations, indeed, of all humankind. Ultimately, they provide the conditions under which first- and second-dimension rights are realized, and should accordingly be called rights of humankind.[31]

In the last two decades the environment and its significance to human life has increasingly become the focus of national and international attention. At the same time the ecological situation in the Sahel has deteriorated dramatically. For the people of the Sahel the human right to a life-supporting environment and the chance of a future worth living for is in jeopardy now more than ever. Human life in the Sahel is possible only if the environment is intact. Grasses, trees, hedgerows, and shrubs do more than provide food, energy, and animal fodder. They also help to preserve soil fertility (for example for cultivation of food crops), prevent erosion, conserve water resources, check or counteract climate changes, and provide a habitat for wildlife. Yet the process of environmental degradation is continuing.

There are many reasons for environmental degradation, but one thing is certain: the symptoms—loss of cropland and forests, depletion of rangeland areas, and shortage of water—can by no means be attributed only to two climatically adverse decades with extremely low rainfall. *Human*-induced environmental

degradation has at least had similarly significant, if not more disastrous, consequences.

Environmental problems in industrialized countries and in developing countries must be seen in a historical context. In the case of the Sahel, humans have been impinging on the natural base of life for at least a century. During the colonial period the western world violated and destroyed indigenous societies and traditional ways of life in the interest of securing hegemony and ensuring the profitable economic development of colonies at the lowest possible cost (although this process did not occur everywhere simultaneously and with equal intensity).[32]

Colonization also sucked traditional economic and social structures into the vortex of change. Because the primary purpose of colonies was to supply raw materials and receive finished products, traditional skills that were related to indigenous needs were not promoted, nor was there any appropriate industrialized development. Although traditional agriculture conserved resources, colonizers were not interested in it because it was too unproductive. Consequently, agriculture was relegated to the margins of the economy, causing the capacity for self-sufficiency to decline.

Colonial powers can be partly blamed for starting to overuse natural resources. For example, the introduction of poll taxes by colonial administrators forced men to perform wage labor and to participate in a cash economy and in production for the market, to the disadvantage of production for home consumption. Plantations were operated with the help of cheap labor. Profits went to a small foreign minority and flowed back to the mother country in most cases. Later, colonialists were replaced with indigenous elites, and although the rhetoric changed, patterns of thought and behavior usually did not. Societies remained split into modern and traditional sectors with few links between them.

Expansion of production for export to Europe, high population growth rates, and boundaries imposed by colonial powers gradually reduced the area available to nomads and their herds. The new boundaries meant that herders and their animals could no longer migrate with the seasons to follow the rain—usually for hundreds of kilometers southward or northward—as they had

traditionally done. Overgrazing became common. The subsequent activities of well-intended colonial administrators and development agents, who drilled wells and vaccinated livestock, led to a further expansion of herds far beyond the carrying capacity of the rangelands. (Carrying capacity is the maximum human and animal population that a given area can support with existing technology, without triggering sustained environmental deterioration.)

Today virtually no African government supports traditional nomadic pastoralism. It is seen as an obstacle to modernization. Trespassing and smuggling problems, administrative difficulties in dealing with nomadic peoples, and the threat (real or perceived) that wandering herds pose to sedentary populations—along with associated problems of political unrest—have also done little good to the popularity of nomads and their concerns.[33]

The expansion of monocultural agriculture into forest areas and commercial use of forests beyond their ability to regenerate have also had ecologically destructive consequences. Lastly, wars and territorial conflicts, provoked not least of all by the struggle over increasingly scarce natural resources, have led to mass migrations and loss of the tradition to conserve natural resources.

Whatever the reasons, environmental degradation has always had the same consequences for people in the region affected. One consequence, loss of biological diversity, has received major publicity only in recent years.

6.2 Loss of biological diversity

Numerous international organizations concerned with the environment, including the United Nations Environment Program (UNEP), the International Union for the Conservation of Nature and Natural Resources (IUCN), and the World Wildlife Fund (WWF), have expressed concern about the actual and potential consequences of the continuing decline of biological diversity worldwide, which many observers believe is accelerating.[34]

Biological and natural resources (including genetic resources) that can actually or potentially be used by humans are becoming scarcer while at the same time the global population is estimated to grow by one billion in the coming decade. Unless special efforts are made to protect natural resources soon, future generations will be deprived of their use.

The problems with regard to loss of biological diversity are evident in the humid tropics, where rain forests are rapidly shrinking. Many observers are concerned that the destruction of fragile ecosystems will lead to the extinction of plant species that could be important medical sources of drugs for previously incurable human diseases. Advocates of this argument point to the fact that many substances used in modern medicine are derived from toxins that plants produce to fend off their natural enemies. These toxins are complex chemical compounds. Synthesizing them in the laboratory is extremely difficult and possible only when their structures have been identified. There are many examples of plant-based drugs that have brought about considerable progress in the treatment of various diseases. But only a fraction of the plants that grow in the tropics have been cataloged so far, and very few of these have been systematically studied and classified.

The genetic resources of the Sahel have hardly been studied, but there is a great deal of interest in the traditional plant species found there, because of the highly unusual physiological characteristics of these plants and their ability to tolerate drought, heat, and salinity. There is hope that some compounds produced from plants in the Sahel may be effective against certain types of cancer.[35]

There is less plant and animal life in the arid and semi-arid regions of the earth than in the rain forests. We have little information about the links between loss of biological diversity and the destruction of original forest cover in the Sahel. One attempt to measure the dimensions of this loss was made by comparing the current size of wildlife habitats with the original habitats.[36] Original habitat with negligible human intervention was defined as "ideal maximum vegetation." The estimate of currently remaining habitats was based on a broad range of data that varied greatly in accuracy. The conclusion was that "the figures should be taken

as indicative rather than definitive."[37] Even so, the original habitat areas in the Sahel have become clearly smaller in size (see Table 4).

The most important reasons for loss of biological diversity in the Sahel can be found in the interaction between climatic changes and the increasing pressure of a poverty-stricken population forced to exploit natural resources in order to subsist. Overuse of soils and rangelands and expansion of livestock herds have destroyed forest and vegetative cover. Because fodder is in short supply, farmers in many places find it necessary to kill wildlife that compete with livestock for grazing sites. This has considerably reduced the original game stock, especially large mammals, and has contributed substantially to the loss of biological diversity in the region.

Table 4

Wildlife habitat loss in the Sahel

Country	Original habitat ('000 ha)	Habitat remaining ('000 ha)	Habitat loss (%)
Gambia	1,130	124	89
Senegal	19,620	3,532	82
Mauritania	38,860	7,383	81
Burkina Faso	27,380	5,476	80
Mali	75,410	15,836	79
Niger	56,600	13,018	77
Chad	72,080	17,299	76
Total for sub-Saharan Africa	2,079,641	773,774	63

Data for Mauritania, Mali, Niger, and Chad cover only the sub-Saharan parts of these countries

Source: McNeely, J., Miller.K. et al. 1990. *Conserving the World's Biological Diversity*. Gland (Switzerland) and Washington, D.C. IUCN, WRI, CI, WWF-US, the World Bank. p.46.

In some cases Sahelian governments have taken steps to protect their natural resources and biological diversity by establishing natural parks and protected areas for endangered plant and animal species. Some have also designated partially protected areas, where certain types of land use, such as logging, stripping branches off trees, and hunting, are forbidden. About six percent of the region has been designated as partially or fully protected, five percent of which, or almost 284,000 sq km, is partially protected, and one percent, or 47,000 sq km, is fully protected.

Many experts believe this is not nearly enough for adequate protection of all plant species. The situation with regard to animal life appears to be better. The most important protected areas for animals are the Ouadi-Rimi Ouadi-Achim Fauna Reserve in Chad and the Air-Ténéré Natural Reserve in Niger. Both are recognized as protected areas of international importance for the conservation of ungulates.[38]

The Sahel has a number of important wetlands. These include the Niger River (in particular its inland delta in Mali), Lake Chad in Chad and Niger, and the Senegal River and its catchment area, which extends along the southern border of Mauritania to Mali. These wetlands are extremely important for local populations, their animals, and wildlife. Even though there are hardly any large mammals found in the flood plains of the rivers in the western Sahara, especially the Senegal and the Niger rivers, these areas are still of great importance as a wintering place for migratory birds.[39]

Three important areas have been designated under the Ramsar Convention on Wetlands of International Importance. They are located around Lake Chad and the inland flood plain areas of the Senegal river. These areas are much better protected than wetlands in other parts of the region. However, additional efforts are needed to protect biological diversity in the Sahel. Many protected areas have not been satisfactorily defined, are poorly mapped, or even unmapped, while others exist only on paper. This often makes determining whether a certain area is protected or not difficult.

With the exception of Senegal, parks and reserves are generally poorly, or not at all, managed and protected. Natural re-

serves present numerous practical problems for the poor countries of the Sahel. There is a serious shortage of trained staff at all levels, in particular competent managers, and there is a lack of suitable equipment (including vehicles) and general financial support.[40]

Protected areas can help preserve genetic resources and slow down erosion. For example, conserving the vegetation in proposed reserves such as Air-Ténéré (which is over 40,000 sq km) can stabilize the soil and check runoff. It can even have a favorable influence on the local climate. Protecting such areas preserves renewable and potentially profitable natural resources for use by the indigenous population.

The establishment of parks and protected areas is undoubtedly of great value to present and future generations. In practice, however, several conditions must be met to ensure that these protected projects achieve their objectives. Experience has shown that projects of this kind are successful only if local populations are convinced that protection of the area is in their best interest.[41] If the local population does not cooperate or fails to firmly support it, hunting, poaching, and degradation of natural resources will continue unabated. More important, alternative sources of income or subsistence will have to be found if a local population is cut off from its previous source of livelihood.

The governments of all Sahelian countries have extremely limited financial and human resources to tackle these issues, and the great majority of the region's inhabitants are very poor; they cannot make any financial or other sacrifices to conserve biological diversity. It is very difficult to motivate local populations to get involved and take action because they see long-term resource use as a highly uncertain factor while the costs of foregoing current resource use are immediate. Outside help is thus indispensable for successful protection of Sahel's nature. Several international environmental protection organizations are currently offering help in establishing and managing selected reserves in the Sahel. But the scope of this international aid is much too small given the extent of the problem.

The international community highly values the global ecological, cultural, and aesthetic importance of biological resources

in the Sahel. At least, this is the impression one gets from the concern expressed at numerous speeches at international environmental conferences. Given this global recognition, the international community should be committed to help protect these resources in a concrete, adequate manner. We must hope that this will happen in the near future, for "the next decade may be the last chance to find a new formula for humans and wildlife to coexist in Africa."[42]

6.3 Desertification and the consequences for ecosystems

Since the catastrophic 1969–73 drought, the term desertification has become a household word in discussions about ecological problems. Horst G. Mensching has described the phenomenon of desertification probably best, defining it as "a process that has its greatest impact under certain climatic conditions primarily in semi-arid and subhumid zones inhabited by humans. It is a process of serious ecological degradation that damages land-use resources, often destroying them irreversibly at regional levels, and certainly at local levels."[43]

Desertification causes desert-like conditions to spread to areas where such conditions would normally not exist, given the climate. This process causes a severe decline in the potential for livestock husbandry and cultivation of food crops and other crops. Because it is caused by humans ("desertification" comes from Latin *desertus facere*: to make into desert), desertification does not begin in sparsely populated desert areas but in relatively densely settled regions with steppe and savanna areas, which are ecologically susceptible to desertification.

It is not easy to find an acceptable alternative to the word desertification. Desert formation or steppe formation come close, but they do not reflect the fact that, apart from the effects of insufficient rainfall over many years, humans and their interventions in the ecosystem are the real cause of the problem. Human-induced destruction of the biological potential in ecologically sensitive areas (such as inappropriate agricultural techniques, forced cultivation of food crops in unsuitable areas, and overgraz-

ing) intensifies the impact of drought and sets off a degradation process that has its own dynamics. Wherever the carrying capacity of natural vegetation is exceeded for a long time, the consequence is continuing degradation of the land.[44]

Drought and desertification, as Mensching showed, are closely linked: years of water shortages and great rainfall variability make desertification more acute. This in turn promotes drought and intensifies its effects.[45] Excessive destruction of natural vegetation can in itself cause ecological degradation processes, but these processes lead to desertification only during prolonged periods of drought.

Desertification is not a new phenomenon; in fact it is as old as the history of humankind in the Sahel. There have always been shifting dunes that have buried desert settlements and destroyed the productive capacity of many areas that were once fertile. Already in the 17th and mid-18th centuries travelers and traders observed that the desert was spreading into the Sahel, which was described as an area with the rich vegetative cover characteristic of the humid savanna. The banks of the Senegal River once were covered with clusters of thick-trunked trees. Today most of this area consists of bare sand. Earlier marshlands have also disappeared. As recently as 300 years ago extensive areas of Mauritania were reported to have been covered with dense vegetation.

Since the beginning of the 20th century there have been many discussions about whether the Sahel is drying up and desertification is expanding. The debate waxed and waned as dry spells came and went. Following the 1910–18 drought, French and English colonial administrators believed that the Sahara was expanding rapidly and would encroach on the Sahel. But, as is often the case with debates about pressing issues, interest declined as the urgency of the problem abated, in this case with the return of enough rainfall.

The debate resumed in the 1930s with the publication of *The Encroaching Sahara,* by Prof. Stebbing of the University of Edinburgh.[46] Stebbing postulated that the Sahara was encroaching on the Sahel very rapidly. He supported his argument with his own observations (primarily in northern Nigeria) and his perception

that rainfall was becoming more scarce, village wells were drying up, and sand dunes appeared to be advancing.

In 1949 the influential French forestry expert A. Aubreville popularized the term desertification in his book *Climats, Forêts et Désertification de l'Afrique Tropicale.*[47] He, too, saw human activities as the primary cause of deterioration of the land. He called attention to the fact that the impact of these activities could be perceived far beyond the Sahel.

The issue received little attention in the 1950s and early 1960s, when rainfall was sufficient and well-distributed throughout the entire region. The debate resumed with the onset of another prolonged drought in the late 1960s. The desertification problem aroused considerable international response, not least because of the impact of the catastrophic 1968–73 drought. The high point of this response was the first United Nations Conference on Desertification in Nairobi in 1977.

For the international community this conference was the first confrontation with desertification. Conference participants found themselves discussing a subject about which very little information and reliable data was available.[48] Consequently, the first task that was set was to assess available data concerning the status and the course of desertification. Questionnaires were designed to obtain the necessary information, and governments in affected areas were asked to provide information about the status of desertification in their countries. Among the indicators used were the proliferation and encroachment of sand dunes, deterioration in the quality of rangelands and rainfed croplands, waterlogging and salinization of irrigated fields, deforestation, and the declining availability and quality of groundwater and surface water supplies.

With the help of data gathered in this way, it was possible to categorize the level and severity of desertification as "slight," "moderate," or "severe." Desertification was considered moderate if the production capacity of croplands had declined by about 25 percent and the resource base had deteriorated. It was classified as severe if productivity losses exceeded 50 percent of the land's potential and if restoration of the productive potential

through land reclamation was not considered economically feasible.

These classifications, however, were imprecise and open to vague interpretations.[49] But the questionnaires for the first time showed that desertification really was an international problem of increasing severity, and not a temporary one that would wash away with the next rain.

Desertification was classified as at least moderate on more than 80 percent of the rangelands and on almost as great a proportion of the rainfed croplands. Approximately one-quarter of the cropland areas were severely damaged. According to United Nations estimates at the time, about 70 percent of the rural population of the Sahel was affected by moderate desertification and roughly one-third by severe desertification. Most of those facing possible desertification lived in the most densely populated areas in the region—the rainfed croplands in the southern part of the Sahel.

The widely held view held then that the desert was expanding southward by a number of kilometers every year[50] found its way into the Brundtland Report, World Bank presidents' speeches, UNEP reports, and statements by many organizations concerned with development.[51] Images of a "desert on the move" generated many well-intended proposals, such as the one to plant a "green belt" of trees across the desert in order to halt its "relentless" advance into relatively fertile areas.

Satellite images revealed that vegetation, which had receded during periods without rain, spread northward again with the return of rain following the dry spell of 1984.[52]

Today it appears that desertification is not the result of a relentless, inexorable advance of the desert. Rather, the course it takes is determined by specific local conditions in arid and semiarid areas—areas that vary greatly in terms of their microclimatic and socioeconomic conditions.[53] Although the hypothesis of continual southward expansion of the desert has lost much support in recent years,[54] it is nevertheless obvious today that desertification has spread into the Sahelian zone of western Africa.

We still do not know whether desertification is a temporary, at least partially reversible phenomenon, or whether it causes irreversible damage. We do know that harvests have been

good thanks to abundant rainfall in recent years in areas where desert-like conditions prevailed during periods of drought.[55] Moreover, many ecosystems that appeared to have been destroyed have "recovered" (at least where sufficient biological diversity was maintained to prevent the ecosystem from collapsing).

The extent to which the earth has been affected by desertification is still a matter of speculation.[56] A widely quoted United Nations estimate that 21 million hectares of land are lost each year[57] has not been accepted by the World Bank[58] and other international institutions.[59] There is a lack of expertise, well-trained staff, adequate financial support, and well-maintained equipment in the countries affected to produce reliable information and data that would clarify the issue. In addition, the satellite technology that was initially regarded as the most appropriate tool for monitoring land use[60] has since proven to be somewhat less suitable than originally hoped.[61]

In sum, the methods for monitoring ecological change in the Sahel that have been used so far are far from perfect, and there is good reason to share Falloux's opinion that "a great deal of the alarm about the spread of the deserts is based on very imprecise data."[62] This conclusion is certainly discouraging, especially when we recall that as early as 1977 the United Nations Conference on Desertification expressed concern about the lack of empirical data and urgently called upon the international community to provide the resources necessary to improve data collection. The evidence available today tends to support the conclusion that desertification has spread considerably in recent decades.

One pressing question concerning environmental problems in the Sahel is whether there are any changes in weather patterns, in particular changes in rainfall trends. If there are, what does this mean for the region's future? Since both humans and animals in the Sahel depend on irregular rainfall for their water supply, in most areas water is already by far the scarcest commodity. Consequently, in the interest of the Sahel's inhabitants, there is an urgent need to answer the question of how possible long-term climate change might influence desertification.

A study by the US National Research Council's Board on Science and Technology for International Development (BOSTID)

concluded that the climate in the Sahel zone has changed little over the last 2,500 years, but that the 20th century may have been the driest century in the last 1,000 years.[63] The study also showed that long dry spells have historically been a normal climatic feature of the region. Moreover, the study demonstrates that rainfall isohyets (the meteorological term for lines that join points with equal amounts of rainfall) have shifted southward, and many areas, mainly in the southernmost part of the Sahel, are now receiving less rainfall on average than they used to—areas that formerly had 550 mm of mean annual rainfall in a normal year today receive only about 400 mm. However, there is no agreement on whether this is a sign of changes in the global climate.

Because the Sahel zone lies between the major atmospheric circulation systems of the northern and southern hemispheres, climatic change in the region is influenced by weather patterns in both hemispheres. This makes it extremely difficult to understand or predict change processes, even to an approximate degree. More precise weather forecasts for the Sahel will depend on a better understanding of global climatic processes, which is a priority concern in current climatological research.

Most climatologists are very cautious about forecasting future developments in the Sahel[64] because the impact of global warming on the region's climate is unknown. However, in view of the latest findings about global warming, it would be unduly optimistic to assume that the region will be free of its effects in the long term.

From our present-day perspective, we can be fairly certain that the people of the Sahel will continue to experience years of well-distributed, sufficient rainfall as well as years of poorly distributed, insufficient rainfall. It would therefore be wise for policymakers in Sahelian countries not to rely on unfounded hopes for extended periods of abundant rainfall. In view of the climatic fluctuations that can be expected in the future, as well as the high probability of recurring droughts, precautionary policies are certainly in order, even without the pressure of catastrophic events. It would be desirable to see such policies be given precedence to general improvements in natural resource management

for combating desertification[65] and to elaboration of food security programs.

The fact that we now know too little about long-term climatic trends and their ecological impacts should not be a reason for postponing action. Currently available knowledge has already made it clear that even short-term climatic variations can produce considerable changes in plant and animal life in the areas.

Studies by the French research organization ORSTOM have shown that herbaceous and woody vegetation at a test site in northern Senegal showed great change during years of low rainfall. After 1972, a year with little rain, more than half of the trees of the *Acacia senegal* species died at the test site, and the composition of grasses changed dramatically, with perennials being replaced with nutrient-poor annuals.[66]

The subsequent chain of events demonstrated in detail the interdependence of ecological factors and in what way negative ecological changes cumulate. The fundamental changes in the ecology caused a decline in the rodent population and consequently a decline in the number of hawks and other predators that prey on rodents. Termite infestation worsened because the dead vegetation was ideal for termites to proliferate. When the rains returned, the area recovered only with difficulty. The environment was restored only partly. Fresh growth of grass caused a rapid increase in the field mouse population. Since the mice fed on the young shoots, this population increase seriously hindered the regeneration of acacia species. Regeneration of these trees began only much later, when the mouse population had stabilized.[67]

The ORSTOM study offers evidence for the assumption that even short-term climate changes can have a measurable influence on the environment and eventually contribute to cumulative changes in the ecosystem. It also confirmed the assumption that even microecological changes, such as erosion caused by slow tree growth, can trigger a deterioration spiral. Drought, and the degradation and damage to ecosystems that it causes, has already contributed substantially to acceleration of soil erosion in the Sahel.

The soils of the Sahel are shallow and low in fertility. A certain minimum of vegetative cover is therefore extremely important in protecting the soil surface against the effects of wind and rain. This became clear during the drought in the 1970s. The vegetative cover had died for lack of rain, and bare, loose soil was exposed to the wind, which eroded large amounts of topsoil. This resulted in a considerable loss of important soil nutrients and a significant drop in the productive capacity of the soils. Subsequent rainfall was often too heavy to be absorbed and topsoil was washed away.

In his analysis, Mensching pointed to a number of ecological consequences of long-term rainfall deficits in the Sahel, including the following:[68]

- the elimination of grass cover in many areas;
- the elimination of some bush vegetation as well as acacia stands with flat roots, particularly *Acacia mellifera, Acacia nubica;*
- a drop in the groundwater table near the surface, primarily in the vicinity of wells, and also in *wadis;*[69]
- an increase in shifting sands and the reactivation of some old sand dunes;
- more wind erosion of fine soil components;
- increased evaporation, with drying out of soils and cracking on clay soils.

6.4 Human interventions in nature and desertification

It appears at present that rapid population growth and increasing numbers of livestock are the main causes of desertification in the Sahel. A World Bank publication argued that the region's carrying capacity is under strain and in many places even exceeded because the population has grown too rapidly, which has also resulted in too many animals.[70] The World Bank study estimates that the carrying capacity of the Sahelo-Sudanian zone (the area between the 350–600 mm isohyets and containing more than half of the total population of the Sahel) is about 15 people

per sq km under present land-use practices. Current estimates of population density in this zone put the number of people per sq km at 20, which means that the present pattern of resource use is already exceeding the carrying capacity.

Population density exceeds estimated carrying capacity most markedly in the groundnut basin in Senegal, in Gambia, and on the Mossi Plateau. Here, according to estimates, 24 percent of the population lives on only two percent of the total area, and rural population density is 45 people per sq km. The World Bank study confirms that desertification is most advanced in areas with high population growth rates and in areas where pressure on cultivable land and available firewood resources is the greatest. Ecological deterioration will occur in such areas if no measures are taken to institute sound management of natural resources.[71] (See Figure 4.)

But the World Bank study also points out that there are regions in the Sahel where the population, given the pattern of resource use, is far below carrying capacity. This applies primarily to the southernmost portion of the Sudano-Guinean zone, where carrying capacity is estimated at 35 people per sq km, but where the current population density is only nine people per sq km. For all practical purposes, this constitutes, inter alia, a recommendation for migration into the more humid areas of the south, since the potential there is still great enough to sustain intensified agricultural production. This potential does not exist in the drier regions that make up most of the Sahel.[72]

It cannot be denied that there is a negative interrelationship between high population growth, stagnant technology, and desertification. This interrelationship is the main reason why problem solving is so difficult.

Because there are so few opportunities in the Sahel for gainful employment apart from agriculture, the number of people who must earn their livelihood from the land is continually increasing.

In the past, when the Sahel was less populated, traditional agricultural methods conserved resources over the long term and were thus ideally suited for preserving soil fertility. Earlier land use patterns included fallow periods lasting a decade or longer,

Figure 4

Erosion an population

Expected (line in carrying capacity by the year 2000 without any soil conservation efforts

> 50%

30–50%

15–30%

< 15%

Source: FAO, 1986

which allowed soil fertility to be restored. In addition, people used to take a number of simple measures to combat erosion and sustain soil fertility. Depending on the region, wind-protecting hedges and trees that provided shade were planted, terraces and dams were built to use the sparse amount of water as effectively as possible, and intercropping practices were used. These traditional techniques made it possible to obtain low but stable yields.

Rapid population growth has increased the pressure on croplands. The main feature of traditional cultivation—observance of adequate fallow periods—has suffered as a result. In most cases fallowing practices were completely abandoned and not substituted with any technology such as new seed varieties or fertilizers to enrich soil fertility. The productive potential of the soil declined.

To make up for the ensuing yield losses, new land is continually being brought under the plow. Agriculture is being extended to areas with marginal soils or areas used by pastoralists. Bush and grassland cover have come under considerable stress in recent years due to the competition between small farmers and pastoralists for scarce resources. Pastoralists burn off old vegetation so that their animals can find tender green forage quickly. Clearing the land in this way may be helpful to herders, but in the long term it penalizes small farmers and society in general because it destroys soil fertility and paves the way for erosion. Fire reduces the valuable nutrients in grass and burns animal dung and it destroys trees and shrubs that stabilize the soil and recycle its nutrients.[73] Degraded soils cannot absorb rain water, and the soil is washed away.

The relationship between the number of livestock and the spread of desertification is a complex one and has been the subject of much debate. Some of the current ecological problems resulting from overgrazing and destruction of vegetative cover originated in colonial times, which is illustrated by the precolonial history of the nomadic pastoralist people known as the Peul (or Fulbe).

During the rainy season, the Peul migrated to the Ferlo region in Senegal to let their herds graze around seasonal watering places. During the dry season, they withdrew to the Senegal River valley or to the more moist croplands and pastures of the

Sine Saloum, where there used to be sufficient forage for their livestock. When farmers in this region were encouraged to increase the production of groundnuts for export, the Peul were barred from the area. At the same time, the development of irrigated fields along the Senegal River prevented herds from gaining access to riverine pastures. This disturbed the balance between agriculture and pastoralism. In the mid-1950s tubewells were drilled and water points were established to "stabilize" the Peul. Given these restrictions on their grazing land, Peul herders remained in the Ferlo region for better or worse throughout the year.

While these changes were taking place during the 1950s and '60s, successful vaccination programs helped reduce the livestock mortality rate, resulting in a substantial increase in the number of livestock. When drought set in after 1968, pastoralists could no longer migrate to the traditional grazing areas they had sought out during dry years in earlier times. Consequently, vast numbers of animals perished, not so much from a shortage of water as from a lack of forage.[74]

The growing number of livestock on the restricted rangelands available to the Peul upset the ecological equilibrium. Overgrazing caused nutrient-rich perennial grasses to be replaced with annual grasses, and later by unpalatable herbaceous plants and shrubs. This form of degradation was further aggravated by livestock trampling and leveling the soil. If the soil breaks up under such conditions, roots are exposed and torn up.

Rangeland degradation is a classic case of the conflict of interest between the individual and the community—an example of the "tragedy of the commons." It occurs wherever individual rights of use (in this case grazing rights for privately owned cattle) co-exist with common ownership. Because grazing areas belong to the community as a whole, individual herders have no incentive to adjust the number of their livestock to the rangeland carrying capacity if others do not do the same. The inevitable result is excessive use of common property for private gain.

Although rangeland carrying capacity rarely correlates with the subsistence needs of nomadic peoples, overuse is also accelerated by patterns of thought and behavior. Many pastoral-

ists in the Sahel regard cattle as a symbol of wealth rather than a commodity to be traded. Accordingly, they keep their livestock as long as they can rather than parting with them when the conditions worsen. Many observers of the Sahel believe that ecological improvements on rangelands and reduction of environmental stress will be possible only if there are changes in land tenure. Specifically, this means allowing individual land ownership (rather than communal rights of use). This would entrust individual users with the responsibility for the preservation of resources in grazing areas, providing them with an incentive to conserve the land.

Others, from both theoretical and practical points of view, argue that traditional arrangements have their own system of checks and balances (if they are allowed to function), and that nature will preserve the balance between livestock and carrying capacity on grazing land.[75] Allowing such traditional arrangements to continue may mean accepting the death of entire herds due to water or grass shortages, as well as implementing vaccination programs more selectively.

The growing livestock population, and the concentration of herds at water points in particular, have contributed greatly to deterioration of the Sahel's resource base over the last 30 years. Depending on the season, cattle cannot be more than 15–30 km away from water points. During the dry season this puts tremendous pressure on limited rangelands, resulting in overgrazing.

Ill-conceived forms of state intervention have also had negative ecological impacts. One example is a government program to stop traditional nomadic pastoralism by installing communal water points. Traditionally, those who constructed a well had priority rights to its use. The absence of this time-honored form of control has resulted in overuse of scarce rangeland resources, which in turn has caused soil fertility to decline severely.[76]

In spite of all these negative developments, it must be said that vegetation in the Ferlo region showed an astonishing recovery when the rains returned. This grassland recovery demonstrates the remarkable resilience of the vegetation. It also indicates that we must be cautious in judging the extent and the depth of

the resource degradation that results from overgrazing. This is not to say that desertification is not a serious problem in semi-arid areas such as the Ferlo; it certainly is. It is imperative, however, to view regional ecological problems not in isolation but in context, along with other factors such as social and economic realities. Although general statements are of limited value, there is still sufficient reason to agree with IUCN's view that an appropriate amount of destocking will be necessary in the Sahel if the damaged ecosystem is to regenerate.[77]

Population growth and the accompanying increase in the number of livestock have also contributed substantially to deforestation of remaining shrubs and trees. Although the problem is urgent, there is a lack of reliable data about forests, woody vegetation, and trees. This lack of data is common with regard to natural resource inventories in the Sahel. The largest forested areas are in Chad, Senegal, and Mali. While there are very few actual forests in the central Sahel (the 200–500 mm rainfall zone), trees are in fact a predominant element in the thornbush savanna landscape in the area.

According to data compiled by the Tropical Forestry Action Plan in 1990, three percent of all trees are lost every year, which is high by international standards.[78] Other studies have found similar figures for specific regions. Between 1972 and 1977, for example, approximately 60 percent of the protected forests in the Senegal River valley were destroyed, and more than half the natural forest cover was affected.[79] In view of the minimal afforestation and reforestation efforts being made—which occur on less than one percent of the forest land annually—forest cover could virtually disappear in the Sahel within the next 30 years.

Although there are many reasons for the rapid deforestation rate, most observers seem to agree that one of the most important reasons is the increasing demand for energy in urban areas, above all the demand for charcoal as cooking fuel. Senegal's urban population (34 percent of the country's total population) used 54 percent of all the firewood in the early 1980s.[80] It has been estimated that the present annual rate of firewood consumption exceeds the mean annual growth of tree stocks and forest reserves

in the Sahel by 30 percent. This means that present demand can be met only by exhausting existing wood supplies.[81]

The great demand for firewood and the growing gap between supply and demand have accelerated the development and the availability of alternative energy sources (such as gas and solar-powered stoves[82]). But because firewood has traditionally been a "free" commodity, no other energy source is as economical under present conditions. As incomes rise, or where they are already high enough, people seem to be able to afford the higher prices of "cleaner" and higher-quality fuels such as kerosene, liquified petroleum gas, or ethanol. A drop in the demand for firewood can be expected as a result. But for most of the Sahel's inhabitants there is no alternative to firewood currently. Therefore, the search for inexpensive fuels" and efforts to increase the efficiency of traditional wood-burning stoves continue to be very important goals. Research and development with regard to the latter have already yielded positive results.[83] However, more efficient stoves are being accepted only slowly in the Sahel, which is typical when new technology is introduced into traditional societies. Even if these new stoves were accepted much more readily, it is unlikely that they would substantially reduce the demand for firewood in the region in the near future. A considerable increase in supply will be necessary to meet the demands of a growing population.

In recent years, rapid deforestation has caused unprecedented ecological degradation in rural areas in the Sahel. The main impact has been on soil fertility. Trees play an important role in the recycling of soil nutrients. As a rule, the mineral elements stored in a tree are returned to the soil by litter, fruits, deadwood, decomposition of roots, and by nutrients washed from treetops by rainwater. Deep root systems, such as those of the widely grown albina trees, help to ensure that nutrients are brought up from the lower soil layers to enrich the topsoil. This nutrient "recycling" plays a major role in improving soil fertility. Experiments in Senegal and elsewhere have shown that such recycling has a positive effect on crop yields.[84] But once trees have been cut, for example to obtain firewood or clear land for agriculture, their

potential benefits to the soil and their influence on the microclimate are lost.

The extent of environmental damage caused by deforestation varies from place to place. Deforestation has caused gully erosion in areas where deforestation has taken place on a large scale. Soils not stabilized by root systems result in the formation of dunes. Deforestation leads to soil moisture loss, the scarcest natural resource in the Sahel. Tree cutting removes shade and barriers that serve as windbreaks, and allows the wind speed to increase, which leads to greater evaporation, and thus to a drop in soil moisture content and vegetation. This in turn increases the potential for rain and wind erosion.

Deforestation has other negative consequences. Women, who are usually responsible for collecting firewood, must walk greater distances when firewood supplies become scarcer. Alternative materials that contain nutrients, such as cow manure, are increasingly being burned as fuel when they could be much more productively used as fertilizer.

So far, the deforestation problem is not as serious in the Sahel as it is in other parts of the world, such as India. But if the fuel problem is not solved, it could well become a major environmental concern in the years ahead.

7 Women and the Struggle for Survival[85]

Desertification has changed the lives of the people of the Sahel enormously. Women in particular are the victims, as they always are whenever living conditions are precarious. Women perceive desertification as especially radical and painful, because it makes their daily work load even more difficult.

Women know that, for the most part, they are alone in their struggle for survival. Since increasing numbers of young men migrate to urban centers and coastal countries, the role of men in performing duties and obligations is declining. Consequently, women's work loads and responsibilities have become greater, but they have not enjoyed a corresponding increase in influence and opportunities to assert themselves.

In 1988 the Club du Sahel commissioned a survey in which women in six countries were asked to describe the impact of desertification on their lives.[86] The answers are remarkable in several respects. All women ranked the more difficult household work first among their concerns. Next came concerns about deforestation and, interestingly, increasing self-awareness and women's efforts to organize, which were mentioned equally often. In fifth and sixth places came the exodus of men and, surprisingly at first glance, the increasing birthrates. Water shortage came ninth and famine last. Women very clearly see that desertification has changed the entire context of their lives and not just deteriorated the physical conditions. Only one-third of the women expressed concern about the ecological consequences of desertification; the remainder was more concerned about socioeconomic changes.

7.1 Production and reproduction in a 100-hour working week

"Housework" in the Sahel (fetching water, gathering firewood, and acquiring and preparing food) is hard daily labor and makes extreme demands on the time and strength of rural women everywhere in Africa. These tasks have always been very arduous under the scarce desert-margin conditions in semi-arid regions, but they have now become even more of a burden. When there are not enough millet stalks available, women have to find something else, such as leaves or fruit in an environment where trees have become rare. With water and firewood becoming increasingly scarcer, journeys to obtain them are becoming longer. "In the past you wouldn't even consider to bend down for this," says an old woman in Burkina Faso, showing a stick no thicker than a finger. "Today you think it's a good piece of wood."[87]

Depending on the season, a well may be as far as 10 km away, which means a hot and dusty 20-km trip every day just to fill a water container. At the well, women often have to cue up. A woman from Niger commented, "Watering places have replaced our homes as places of worship because we spend so much of our time there."[88] They start out early in the morning, when it is still dark, to be back in the afternoon to do all their other tasks.

Gathering firewood, milling, cooking, washing, and child care are tasks that easily extend the workday to 14 hours, adding up to a 100-hour working week. And this is "only" a woman's household work—the work that typically goes unnoticed and unpaid throughout the world. It does not include any of her many other tasks, such as agricultural work, and it produces no income whatsoever. Water scarcity and firewood shortages, which have been a burden for centuries, are even greater problems. At the same time, the usual agricultural tasks, animal keeping, handicrafts, and trade have become not only more difficult but also more crucial to survival. As men contribute less and less to the family income, women try to expand their productive role to earn an income and ensure a subsistence.

Women are also directly faced with the consequences of land degradation. "In the past, small plots would give you a good

harvest, even if there wasn't much rain. Trees and grass allowed the soil to absorb water. Now water runs off quickly and cuts grooves in the soil. You can't harvest anything . . . ," says the president of a women's group in Burkina Faso.[89]

Soil degradation results in less land for agriculture and more competition for relatively good soil. Men have the advantage in this situation. Many women complain that they either have no land or very little land, or that the land they have is poor. Since the droughts, they have had difficulty getting access to land. "A man first takes a field for himself . . . , then he gives us whatever is left."[90]

It is almost always exhausted land on which equally exhausted women toil. With trees, traditionally important sources of food, becoming scarce, there is simply nothing to harvest, including the raw materials from which traditional medicines are made. "Trees have become stingy," says a peasant woman in Mali.[91] Women see trees first as sources of food and medicine and only second as firewood sources. They rather resort to brushwood and even animal dung, which should really be used as fertilizer, as cooking fuel. Women sometimes complain about the unpleasant smell of dung and how it spoils the taste of food.

The raw materials used to make clothing and mats or to construct houses are also more difficult to come by as a result of desertification. "You can make nice cushions from the skin of fat animals" says an elderly woman in Mauritania.[92]

Given their poor nourishment, hard labor, frequent childbirth, and poor medical treatment, it is no wonder that Sahelian women are often in alarmingly poor health. A good example is the maternal mortality rate, which is still 100–200 times higher in the Sahel than in, for example, Switzerland. And even in light of the low overall literacy rates and the low average number of years of schooling for people in Sahelian countries, women are still much worse off than men (see Table 5).

The energy of women is being overtaxed. Conservation of energy is an urgent matter in the Sahel, and it is the energy of women that needs to be conserved most of all.

Table 5

Social disadvantages of women in the Sahel

Country	Maternal mortality rate[a]	Schooling[b]	Literacy rate[c]
Niger	850	50	85
Mali	850	20	54
Senegal	750	31	48
Mauritania	800	20	45
Chad	800	33	43
Gambia	1,000	22	41
Burkina Faso	750	67	32

[a] For 1988, per 100,000 live births. Source: UNDP, *Human Development Report 1994*. Washington, D.C. 1994. Table 11, p.150 ff.
[b] For 1992, as a percentage of the average for males (male average indexed to equal 100). Source: UNDP, Op. cit., Table 9, p.146 ff.
[c] For 1992, as a percentage of average literacy rate for males (male average also indexed to equal 100). Source: UNDP, Op. cit., Table 9, p.146 ff.

7.2 The exodus of men

The privileged position of men in a patriarchal system, if it is ever questioned, is justified usually by the fact that men are considered to be the family's providers. Although, in Africa, they never really were the sole providers, it has been more true in the northern, Arabic parts of the Sahel than in the southern parts, which have black African populations and traditions. As the number of livestock has dropped in the last two decades and millet yields have declined due to drought, the ability of men to contribute substantially to supporting their families is declining.

In many societies where seasonal migration has been long known, the exodus of men to coastal countries and regions continues, and nobody can predict when they will return. Despite great regional variation and differences in tradition, men are

absent for brief or prolonged periods in every society to some extent, with far-reaching consequences for the economy as well as the social structure. It may be a matter of "honor" for them not to return until they have saved a certain amount of money or purchased an sufficient quantity of gifts.

The absence of men is a very hard fate for women, particularly for those who live on the fringes of the desert. In addition to their traditional work, which is becoming increasingly difficult, these women must carry out extra tasks, such as cultivating crops for the market or for home consumption. There is also pressure to earn some money because certain expenses, such as taxes and fees for water supplies and health care, as well as expenses for daily necessities such as sugar, salt, tee, matches, soap, and school supplies, have to be met, even if the men do not (or cannot) send money.

The situation of women who are left behind depends on the ethnic group to which they belong and the traditional division of labor between the sexes. Often, the members of formerly privileged classes are particularly hard hit. One Songhai noblewoman says, "Before the drought aristocrats like myself had never used a mortar .... Now a woman goes into the fields and sows just like a man, but harvests nothing."[93] Fair-skinned Mauritanian women, who traditionally hardly had to perform labor, now find it necessary to work, but they are ill prepared and sometimes find it humiliating.[94]

Women who are used to working outside the family seem to be in a better position to take advantage of aid programs and to till the land on their own. But even if a woman succeeds in growing a crop, she usually cannot decide what to do with it if her husband is absent. When he returns, the crops produced on his field once again belong to him.

7.3 Disintegration of the family structure

Women who are left behind with the elderly and children often feel abandoned and find that their family life is at stake. "The animals are dead and the men have gone off to look for work ...,

but we have no choice. We are the only source of support for the family, and we have to fight it out alone," says a woman in Mauritania's Tagant region [95] For all practical purposes, these women lead the lives of widows but without the chance of starting over with another partner. They also complain about disobedient children who refuse to carry traditional tasks and who do not recognize a mother's authority: "Nowadays children can just turn their backs on you."[96] Some younger women have started to accompany their husbands to coastal regions. They are often envied by those staying behind.

With the absence of men and the burden of the bride price, many young women may end up as old spinsters or become pregnant without getting married. Now there are 25-year-old single women, which would have been unthinkable in earlier times. It is considered strange if women stay single. But if they are single with a child, they are condemned to a life in the margins of society.

Since men cannot tell when they will have saved enough to return and get married, families now often marry off their daughters as second or third wives to older men who can at least pay a modest bride price. Polygamy, although not widely practiced, has always been permitted in the Sahel, and it has become more popular to spare young women a long period of waiting and engagement.[97] Polygamous marriages do not often last long. Young women frequently return to her parents after several years, perhaps bringing along one or more children.

Surpristingly maybe, drought has not stopped or even slowed down population growth. On the contrary, there has been an increase in birthrates. This is caused by the breakup of traditional family structures, illegitimate marriages, shorter breastfeeding periods, and disregard for earlier taboos that were strictly adhered to following childbirth. Many women, in particular older women, are critical of giving birth to the next baby too quickly too often. "Having children without the means to support them only brings tears."[98] The elderly feel overburdened by having to look after children and they regard frequent childbirth as a decline in morals of a promiscuous younger generation. They blame men in particular: "Women never provoke men . . . , but men just don't

care if women and children suffer."[99] Younger women, who are more shy of men than older women, are less likely to make such bold statements, but their wish for less frequent pregnancies is often expressed. Even in traditional pastoral societies, children are no longer seen only as a blessing: "Children see the drought and are attracted to it in large numbers to make their parents suffer . . . . Now we have lots and lots of children; they are like flies."[100]

Evidence gathered by Marie Monimart indicates that women would like to have fewer children, while men feel a large number of offspring testifies to their manhood. Men are still in control in matters of reproduction. For women in the Sahel, there is no such thing as the right to determine the size of one's own family.

Another consequence of frequent childbirth and heavy workloads is the neglect of traditional obligations in raising children. Mothers are unable to pass on traditional knowledge handed down from earlier generations. At the same time, daughters are often unable to attend school because their mothers badly need their help. There is a danger that the next generation of women will be as illiterate as their mothers' while it will not have absorbed their mothers' centuries-old knowledge of how to survive.

In the Sahel, marriage no longer means security for women. It is undermined by the frequent absence of men, more frequent divorces, and rivalries with second and third wives. Marriage no longer means that a woman's material needs will be provided for. Yet, women value marriage and children highly, because a husband and (male) offspring gives them status. Even women themselves define other women according to these criteria. A single woman counts for nothing; only as a married woman does she have a hope of earning a socially acceptable position one day. But marrying in extreme poverty means she will have many obligations that are hard to fulfill, without the satisfaction that she will be provided for.

7.4 A new self-awareness

In the survey on the consequences of desertification for women (see p.61), women named their concern about the disappearance of trees as frequently as their concern about their new activities and independence. "We can't just sit and wait anymore for a man who doesn't return. A woman has to stand up for herself and think about how she can feed her children and survive on her own," says one woman in Mauritania.[101]

Spitteler has given a vivid description of how Tuareg women in the Air Mountains of Niger patiently wait for their nomadic husbands to return from camel trips into Hausa territory. If all goes well, they come back with millet and clothing.[102] It is up to the women now to feed both their children and the goat herds, even in periods of drought. Many women seem hardly aware of the tasks they have always performed, but they are very proud of their new, additional tasks. Through these new duties they have gained a new feeling of responsibility and faith in their own strength. The old division of labor based on sex is no longer valid. In many places 40 percent or more of the households and the production units are headed by women.

Men do not necessarily approve of the fact that women are ready to accept responsibility and willing to take initiatives; they often regard these developments with suspicion, which increases the potential for conflict between the sexes.[103]

Many women's associations have been established at the village level. The aim of these associations is to ensure the survival of the family. Nowhere do associations serve to satisfy personal needs. The women's groups are also partner organizations in the implementation of nationally and internationally initiated programs to combat the advance of desertification, reclaim lost croplands, and replant trees and shrubs. Development agencies have recognized the increased activity on the part of women, and have gladly made use of it. Women are also willing to be drawn into community work because they have no other choice, given their efforts to ensure the survival of the children and the elders who depend on them. They gain self-awareness and independence in

the process. Hopefully, this new assessment of their role will continue to hold true.

7.5 The struggle against the desert

All Sahelian countries have programs to check the advance of desertification. Many of these programs are carried out under the supervision of the Comité Permanent Inter-etats de Lutte contre la Sécheresse dans le Sahel (CILSS–Permanent Interstate Committee for Drought Control in the Sahel). CILSS has published a report on 21 of these projects, many of them at the village level. Some of these case studies describe in detail the role of women in efforts to combat desertification.[104] Observations made in the course of these projects are confirmed by many other reports from development cooperation projects. Highly motivated women actually perform work that men were initially shown how to do.

Often, however, women do not gain any immediate benefit from their considerable additional workload. In Burkina Faso, for instance, women, not men, worked hard carrying rocks and water for the construction of dikes to protect fields that belonged to men. It appears that when women are equally well trained for work as men, the effectiveness of the technology being applied is enhanced. Women are proud of their work and may even overlook the fact that they will not be allowed to till the land that they helped to rehabilitate.

It was reported from a project in Niger, where small dams were used to reclaim cropland, that the reclaimed land would be allotted to families who carried out the construction and the planting. In many cases families had women to do the work. In the end, the land did not go to them, but to the (male) head of the family. There were a few exceptional cases where women, as heads of the household, participated in the project in their own name. But most of the women, who did most of the work, were rewarded with a community orchard and a vegetable field. Now, women ask what happens in the case of divorce and wonder whether their efforts have provided them with any rights.

In this project, women were paid with food, which they welcomed because it meant that they and their children would profit from the work. Men performed wage labor in the project. The women were able to sell part of their food rations and thus earn a bit of cash, which allowed their husbands to feel free to look for work in the city. Payment in food does raise problems, however, because children, pregnant women, and nursing mothers have to work harder than is good for them to be able to get at least something to eat.[105]

In one region of Senegal that has been severely affected by the exodus of men, a tree-planting program was a success because it had been implemented entirely according to the ideas proposed by women's groups. The women specifically requested that trees of medicinal value be planted, even though this did not immediately improve their living conditions.[106] In many cases it became clear that women had very different ideas about tree selection than men. Wood production was the least of their concerns; food, animal fodder, and medicinal use were of greater importance. When the participation of women is assured not only in the work but also in the conceptualization and planning of the measures to be taken, it considerably enhances the chances of success of a project.

Women also think more economically. They favor firewood-saving stoves because it means they have to purchase less fuel. Men, acting according to traditional role models, refuse to give them money for this, even if they have it.[107]

7.6 The demands of women

Overexploitation of natural resources is currently a salient feature of life in the Sahel, and this includes overexploitation of one of the region's most important resources—the labor of women. Development planners and those responsible for environmental management programs in the Sahel have come to recognize that success will not be possible without the commitment of women, and they now engage women purposefully.

Women have gained self-respect and want to take their fate into their own hands. They are organizing for this purpose and they are making an effort to protect and conserve the basis of their livelihood. At the same time they run the risk of becoming instruments, used and exploited by planners and experts who want to achieve their own goals without taking into account women's interests or saving women's strengths. Women in the Sahel should cooperate to achieve the human right to a sound environment. They are only too ready to do so, but they can do this only if they are first guaranteed human rights of the second dimension, namely, economic security to ensure survival, and access to income, information, and good health.

More specifically, the workloads for women need to be reduced, they need access to water and firewood, stoves that conserve firewood, and in many areas, gas cookers as well as gas. They need grain mills and sufficient food supply, which means they also need land. When they perform community work they must be appropriately compensated, either in cash or in kind. Monetary income, modest though it may be, has now become necessary to survive. Women need to be able to earn an income. They need know-how and the chance to associate, exchange ideas, and organize. Mothers need enough time, so that they can send their daughters to school and still pass on traditional knowledge. They need breaks, both in their hard daily work and in the rate at which they give birth. They have the right to a family, but also the right to determine how large their family should be.

The demands Sahelian women must make if human rights were also to apply to them are modest enough. Many of their demands are likely to be met for reasons that have more to do with efficiency than with justice.[108] Women have an independent right to satisfy their basic needs (which are the same as those of their children), not just a right derived from the goal to extract the maximum amount of output possible from them.

This also means genuine participation in the planning and selection of measures to combat desertification, not just approval of plans made long in advance for the sake of form. Above all it means that women must get their share of their own labor. When women, who are most affected by a project, are included in

planning from the outset, it becomes clear that they know very well what is important, and that this is often a far cry from what appears obvious to foreigners and officials from the national capital.

In a world where it seems that the future can be planned by technology and implemented by technocracy, and where women are defined in relation to men, it is difficult for women to formulate their demands and succeed in achieving them. The drought crises has awakened and released potential creativity in women. This awakening includes a renewed acquaintance with the lost wisdom of previous generations and with a way of life closely tied to the natural environment. Despite the many burdens, desertification also offers an opportunity. Women are experiencing a growing self-awareness through their work and gain more self-confidence. Where conditions have been favorable enough for women to have been granted human rights of the first dimension, many are now banding together to demand second-dimension rights and the human right to environmental protection, and work toward achieving these demands.

8 Sustainable Development

Although science has often duly warned humankind when the world was about to be confronted with a problem of major proportions, warnings mostly go unheeded because they are issued before their time.[109] This has also been true of scientists' concern about the degradation of the global environment. Only with the publication of *The Limits to Growth*[110] (the Club of Rome's first report on global conditions) in 1972 and *Mankind at the Turning Point*[111] (its second report) two years later, has the general public become aware that, unless we adopt more reasonable consumption patterns, there will not be enough global resources to support the world's population indefinitely. *The Global 2000 Report to the President*[112], presented to former US President Carter in 1981, brought similar news, as did the so-called Brundtland Report[113], which, published in 1987, continues to influence the debate today.

The struggle against desertification plays a relatively small role in the efforts toward sound development in the future, but it is of central importance to the countries in the Sahel zone. During the 1970s and early 1980s, numerous efforts were launched to combat desertification on a regional level. Most eventually came to nothing.

In the past, the emphasis was primarily on forms of state intervention. Today there is a preference for decentralization, calling for most of the responsibility for management of natural resources to be delegated to the level of the resource users. If such a policy is to fit the concept of sustainable development, it must have an ambitious two-fold aim: meeting today's food requirements without jeopardizing the ability of a much larger future generation to feed itself. For the Sahel, this means both increasing current agricultural production and conserving the natural resource base so that future generations in the region will be able to satisfy their own food needs.

Centralized resource control dates back to the colonial era. In the first half of this century the French made an effort to protect

and restore forest resources in the Sahel mainly to boost exports and state revenues. In 1904, a forest code was established, patterned after the French system, granting the authority to manage natural resources to the state. The use of forest lands was strictly controlled, and the unauthorized felling of valuable trees was legally forbidden. The forest code was revised in 1935 as a result of the increasing pressure on forest areas from farmers and from nomadic pastoralists who needed land for their herds. The forest service was given the authority to expropriate land and make forests state property to prevent the spread of agriculture. Farmers were granted the right to use forest products, provided that they did not damage the forest.

In the final years of the colonial era the authorities expanded the forest service and became more engaged in forestry research. Efforts to prevent commercial agricultural operations from expanding into forest lands and areas with marginal soils continued. In the mid-1950s colonial authorities in Senegal, where control over land use was still centralized, created a "forest and grazing zone" to arrest the advance of groundnut cultivation, which was seriously exhausting the soil. The task of the forest service was to protect the zone rather than develop it. Farmers who failed to observe the restrictions on land use in the zone could be penalized. The colonial authorities also became increasingly concerned about degradation, as continued population growth put pressure on the land. They tested some of the techniques designed in the USA to halt the spread of erosion, including water retention basins, dams and furrows, and intercropping techniques to conserve soil fertility.

These efforts were not very successful, however, and were never practiced on a very large scale. A major reason for this lack of success was failure to allow the community to participate, which is indispensable in development efforts. Community participation means involving local land users in analyzing problems, in discussing and decision-making, and finally in implementing technologies that are based on common consensus.

The first years of the post-colonial era in the Sahel coincided with a 15-year period of good weather conditions, with fairly plentiful and well-distributed rainfall. The period came to an end

with the drought of 1968–73, which started at a time when traditional relationships between sedentary populations and nomadic pastoralists had begun to break down and both human and livestock mobility had been greatly restricted by various political and social measures. Neither the governments of the Sahelian countries nor the region's rural inhabitants were prepared for the subsequent catastrophe. The drought caused untold misery and immense losses of human and animal lives, and made the Sahel the focus of much international attention—but not until more than four years after the drought began.[114] International aid, such as food aid, grew quickly in the following years, making the Sahel zone one of the world's most favored regions in terms of aid received. To control the drought in the Sahel, the Sahelian countries formed the CILSS in 1973 (see also Chapter 7.5). In 1977 the Club du Sahel and the CILSS adopted a common strategy for development of the Sahel.

The strategy gave top priority to increasing the agricultural production of commercial crops in humid areas, in particular cotton and groundnuts. Increased investments in irrigation systems were planned. Agricultural development was to be promoted through "disaster-area projects" that aimed to improve the infrastructure in specific regions and give credits to farmers so that they could obtain the inputs they needed to increase production. Livestock projects were also designed. One approach involved fencing off large units of land around water points to encourage nomadic herders to settle. As part of the efforts to combat overgrazing, one program promoted the marketing of livestock that were ready for sale.

Since the extent to which trees were being cut was a matter of particular concern, the biggest investments were planned for the forestry sector. The importance of forestry, especially with regard to firewood, timber, and environmental stability, and the added value of balanced agroforestry, has since been generally recognized.[115]

CILSS' strategy mainly emphasized the protection of existing forests, although it also paid attention to state-controlled plantations of imported species, mainly eucalyptus.

The measures necessary to carry out the strategy required substantial external financial aid. Because donor countries and organizations recognized that the problems to be dealt with were so great, this aid did materialize. In 1971 the countries in the Sahel received US $196.5 million in aid. In 1975–86 the amount of external aid for all Sahelian countries more than tripled, growing from $600 million to over $2 billion. By 1992 the Sahel received more than $2.6 billion.[116]

The results of this aid were disappointing, however. Most of the reviews commissioned during the 1980s concluded that little had been achieved with the more than $12 billion in aid that was given between 1975 and 1983. Most donor countries supported projects for developing irrigated farming, but this accounts for only five percent of all agriculture in the Sahel. Promoting rainfed agriculture, which is more typical of the region and produces 95 percent of all its cereals, would have been more effective and efficient.[117]

Environmental projects and afforestation projects also received little support. Rural populations did not accept programs for new rainfed-agriculture technologies and continued to use traditional agricultural techniques. Irrigation projects developed slowly and proved to be costly, while livestock and range management programs barely improved the existing systems. Although authorities recognized the seriousness of the environmental problems and especially the firewood situation, investments in these areas were too small to achieve adequate results. Where attempts were made to deal with such problems, costs were high and success was modest.[118]

Studies to find the reasons for the lack of success all came to the conclusion that the aims and assumptions of the international donor community had been unrealistic from the start. It became rapidly apparent that experiences from other regions and development models from other countries could not simply be "imported" and applied to the Sahel. The lesson learned from these failures was that there was no universal approach for sustainable development. Different, specially designed approaches would have to be tried out on a case-by-case basis.

The agroforestry example clearly illustrates how development policy has changed since the 1960s. In the colonial era and the early post-colonial years, the emphasis was on centralizing forest control to the state, including restricted access to forest lands. Development efforts concentrated on establishing state-controlled plantations to increase firewood and timber supplies and to stabilize soil fertility. The costs of this kind of intervention rose rapidly, and the drop in profits that resulted from removing natural vegetation and planting imported species was much greater than envisaged. There were also serious management problems. There were no funds to cover operating costs, and local forest services were unable to achieve and maintain an adequate level of production.[119]

The unsatisfactory results on the plantations prompted a move toward "rural forestry," which involved dividing up the plantations into village-level plots. This experiment, too, was a disappointment because the plots were widely dispersed, making monitoring and maintenance expensive. Moreover, communal planting efforts carried out under the supervision of the forestry service were unsuccessful because the distribution and cultivation of seedlings was a problem. Lastly, block planting methods used in many of the projects were hardly accepted by the local population because they did not take account of traditional land use patterns.

Lack of success in such efforts has led to a greater commitment to include local residents in all aspects of agricultural development. An evaluation of earlier forestry projects showed, for example, that local farmers were less enthusiastic about the creation of village forest plots than expected, partly because of the historic unpopularity of the forest services in the Sahel. But there was also a failure to institute an adequate reform of rural policy and corresponding legislation prior to the launching of rural forestry programs. A top-down approach in design and implementation, rather than an approach from the bottom up, was a further weakness of these projects.[120]

A lesson was also learned from the costly plantations of imported species. Today, *Acacia albida*, an acacia species indigenous to the Sahel, is considered very important in agroforestry

because of its many beneficial qualities.[121] It grows in the light, sandy soils of the region and loses its leaves during the rainy season, allowing sunlight to reach the crops planted beneath the trees. Its leaves are rich in nitrogen and thus have a fertilizing effect, while bacteria in the root network enhance the soil's nitrogen content. Acacia wood can also be used as fuel. Other studies have shown that when trees and crops are grown together, the resulting interaction also limits the spread of erosion.[122]

The current trend in agroforestry is a good example of the sustainable development concept. Studies have shown that current agricultural and forestry practices are yielding good returns, even after environmental costs are calculated.[123] In Niger, the planting of protective hedgerows led to an over 20-percent increase in the production of cereals. One kilometer of hedgerow was sufficient to cover the annual wood requirements of 250 people. In other countries maize was planted between *Leucaena* hedgerows because the leaves of this shrub increase the effect of inorganic fertilizers.[124]

8.1 Nongovernmental organizations

The search for alternative ways to promote sustainable development and the realization that broad involvement from local populations will be necessary have led to a considerable interest in the work of nongovernmental organizations (NGOs). A report to the Club of Rome illustrates the successes of NGOs and how they operate.[125]

There are many national and international NGOs operating in the Sahel—over 200 from the USA alone.[126] The advantages of most NGOs can be found in their work at the grass-roots level and in their flexibility, which is great enough to allow for unorthodox approaches. NGOs have a capacity to sense local needs, listen to people and take their traditional knowledge seriously, and make local populations integral partners in development rather than the objects of development. This has led to an unusually high success rate in development efforts based on community participation. An additional major, though not exclusively positive,

factor is that NGOs are less bureaucratic than other organizations. They are also freer from the distrust that many rural people in developing countries have about the activities of governments and government officials.

NGOs are also open to criticism. They guard their independence so fiercely that they usually refuse to collaborate and cooperate with other organizations working in a project area. They carry out their work with a great deal of good-will but often without sufficient professionalism (e.g. in management or technical areas).[127] Nevertheless, the Club of Rome found these points to be relatively insignificant.

In 1988 the Club du Sahel surveyed eight major projects designed to promote sustainable development that were carried out by NGOs in five Sahelian countries.[128] These projects are listed in Table 6, where they are described on the basis of the technologies they employed and the effects they had on production and on resource conservation. The results of these projects shed light on the potential for developing sustainable systems and also show the constraints on further extension of the technologies.

All the technologies introduced into the project were low in cost, and all had a positive impact on the local population in one way or another. For example, in Burkina Faso, OXFAM promoted the construction of simple, low embankments made of rocks to retain water, which proved to be productive and conserved resources. This success was all the more gratifying since previous efforts by the state to develop more complex techniques for conserving water were costly failures. (Attempts had been made, for example, to check soil erosion by constructing dams and ditches, which actually accelerated erosion because the dams were so poorly maintained that they broke, causing the soil to wash away.) The NGO projects envisaged simple and inexpensive constructions that could be carried out by local land users, who would subsequently be able to maintain the structures themselves. Local producers also benefitted financially from this approach.

These case studies show that the NGO projects were ecologically sustainable. Such projects should not, however, be seen as a panacea for improved resource management. Because

Table 6

Environmental protection technologies and their impact

Technology	Risk reduction	Effects on production
horizontal rock ridges	• improved water supply	• higher yields • improved fertilizer efficiency
soil conservation	• protection of natural yield potential	• more stable yields
natural forest management	• resource protection • definition of user rights	• sustainable preservation of woody vegetation and grasses
windbreaks	• less water evaporation	• less labor in wood production
dune stabilization	• protection of cultivable soils	• sustainable agriculture
agroforestry	• crops protected from grazing animals	• higher yields through better protection • higher yields through more forestry
pasture management	• ensured availability of fodder	• improved animal husbandry

Source: *Ecology and Rural Development in Sub-Saharan Africa: Selected Case Studies*, Club du Sahel, Paris, 1988.

Conservation effects	Potential for sustainable system change	Constraints for further technology extension[a]
• less water erosion	• more intensive cultivation possible	• soil fertility • *labor*
• less water erosion	• less erosion allows intensification of agriculture	• limited economic incentives • *labor*
• restoration of grass and tree cover • less erosion through better ground cover	• model for resource management • promotes intensification of cattle breeding	• organization • markets • *policy*
• less wind erosion • leaf litter contributes to soil fertility	• less erosion allows intensification of agriculture	• policy • *labor* • protection of young trees
• revegetation of dunes		• *protection of young trees* • *labor* • *organization*
• leaf litter contributes to soil fertility	• more intensive agricultural system	• *fencing costs*
• restored grass cover within managed area	• adoption of model represents a system change for this zone	• *animal diseases* • animal markets • *fencing costs* • *policy*

[a] Italics indicate partially resolved problems.

NGO projects usually depend on the voluntary contributions of NGO members, and because members' interests may change over time, there is no guarantee that projects will be continued. There are also justified concerns about the policy environment in which NGOs can operate. Most NGOs work within a given policy framework because they have virtually no other choice. As a consequence, they have no chance to influence important developmental policy issues such as price and tax policies, land tenure, rights of ownership and resource use, and funding for rural development.

Ecologically and socially acceptable sustainable development is productive only if it involves cooperation among the state, the private sector, and NGOs. This approach will require an appropriate policy framework that uses all the governmental instruments (legal, financial, and other) to encourage and support sound resource management. Examples include fiscal measures that discourage deforestation while providing incentives for reforestation. There should also be policies that promote conservation in the agricultural sector by providing land tenure security and low-interest loans.

8.2 The need for more collaboration

Because dry spells are a chronic problem in the Sahel, it is necessary to adopt measures that minimize the risks to the population. Above all, this calls for greater knowledge of the region's water resources as well as a wide range of technical programs for obtaining and storing water. Greater political emphasis should also be given to agricultural and forestry policies, and particularly to afforestation programs and the development of alternatives to wood as a source of energy. There are many indications that reducing the number of livestock is unavoidable because there is too much livestock in the Sahel. In addition, access to grazing land will have to be more carefully controlled.

These measures would contribute to restoring vegetative cover and degraded soils. Greater collaboration between international and national agricultural research institutions and organi-

zations will also be required to accelerate the development of suitable technologies for the intensification of land use in semi-arid regions and the conservation of natural resources. This is important to reach urgent goals in these areas in the foreseeable future. It will be necessary to develop drought-resistant species of food crops and fodder crops. Lastly, past experience indicates that decentralization and a broader participation by local populations is required in all efforts toward sustainable rural and agricultural development.

Underlying social conditions will have to change for the benefit of women, and there will have to be equality of opportunity in the vocational and social spheres to create conditions in which women are an integral part of the development process and not merely the means to an end. All development efforts must incorporate these elements. Otherwise, improvements in social, economic, or ecological terms cannot be expected to be sustainable.

9 Problems in Sub-Saharan Africa to Be Addressed by Agricultural Research

9.1 Introduction

Although this book deals specifically with the Sahel zone, many of the development problems and issues in the region are true of all of sub-Saharan Africa.[129] Agriculture, for example, is a crucially important economic sector for nearly all African countries, and many countries face identical difficulties in developing this sector. The need for improved agricultural research as a basis for sustainable agricultural growth in Africa gains in significance if we take a broader view in this chapter by including in the discussion not only the Sahel but all of sub-Saharan Africa.

Agriculture makes a major contribution to economic growth and trade in developing countries. It bears the main burden of providing income and employment to the rapidly expanding population. It also means food security and social welfare. According to data from the Food and Agriculture Organization of the United Nations (FAO) from 1993[130], nearly 65 percent of the total population in most of the sub-Saharan countries were engaged in agriculture. Although urbanization rates triple those of the growth of the agricultural population, the agricultural sector continues to absorb a large share of the population. The agricultural population in sub-Saharan Africa in 1993 was 374 million, which is only four percent less than the total population of the region in 1980. Yet, sub-Saharan Africa is the only developing region where there has been a progressive increase in both the numbers and proportions of malnourished people and a gradual decrease in the per capita output of staple foods. In short, food production has failed to meet the demand for food.

The slowly deteriorating food situation across much of Africa has been aggravated to crisis point from time to time by a

series of drought-related famines that required a massive mobilization of international food and other humanitarian aid (see also Chapters 4 and 8). But drought has in most cases been only the trigger of a situation that probably would have exploded eventually anyway. Food security in Africa is affected by a number of elements besides unreliable rainfall. Poverty is one serious handicap. No other developing region has such a large share of the population that is really poor. The inherent poverty is compounded by a huge relative debt burden: 30 African countries have debts that amount to more than three times their annual export earnings, 40 percent of which must be allocated simply to debt-servicing repayments. The high degree of national fragmentation (47 sovereign states) also presents a problem for agricultural growth. Small countries have difficulty supporting viable agricultural research, and border restrictions hamper free trade, labor mobility, and the traditional migratory patterns of stock herders.

Many of the sub-Saharan African countries have also suffered from civil disturbances since independence and have had little time to develop new institutions of government. Their governments and economies are put under further strain by trying to absorb the rapid expansion of the population, many of whom are lost to the agricultural labor force because they have moved to the cities. This urbanization can, in turn, also mean a change in eating habits from traditional to convenience foods, some of which may have to be imported. In this situation, agriculture is expected to provide export earnings, fiscal revenues, food supply, income and employment, as well as generate self-sustained growth in its own sector.

This would be difficult enough in any case, but it is particularly difficult in a region with a high degree of climatic instability, and where near famines are followed by unmarketable surpluses. Some 40 percent of the total land area in sub-Saharan Africa is predominantly arid or semi-arid, and another 20 percent excessively wet. In the drier countries, the area under irrigation is relatively small and much of this is under traditional systems with a fluctuating water supply and a low cropping intensity. Many soils are difficult to manage for sustainable production, and envi-

ronmental degradation, caused by the pressures of population and poverty, is taking its toll. The problem is exacerbated by serious human or animal diseases such as malaria, river blindness, bilharzia, sleeping sickness, East Coast fever, and now AIDS. Technological change has, in general, been slow and inconsistent, with a low consumption of chemical fertilizer. Relatively few crop areas use improved varieties with high yield potential.

The lack of technical solutions is due partly to the complexity of the problems and partly to the vast diversity of the African agricultural environments and their farming systems. Other factors are a heavy concentration of research resources on agricultural export commodities (in particular in colonial days) and a predominance of a range of food staples relatively unfamiliar to most Western scientists. Also, national agricultural research systems[131] are generally weak and depend heavily on external funding. The communications network is usually very poor, which cuts producers off from knowledge, inputs such as fertilizer and plant-protection chemicals, and credits for their purchase. The general lack of personnel trained in policy matters has often led to unsound macro-economic decisions that have either discriminated against the agricultural sector, or, in the case of exports, exploited it as a source of revenue for other purposes. The development of sound economic and agricultural policies has been further hampered by different ideas among donor agencies and development strategists about how to solve Africa's problems. This has resulted in conflicting advice to governments, which has sometimes impeded progress and distorted national priorities.

9.2 The role of agricultural research

In spite of the apparently gloomy outlook, economic and agricultural growth is not an impossibility in sub-Saharan Africa. After all, only 25 years ago there were serious doubts whether some countries in Asia were viable, but these have achieved a great deal, and none of them could now be written off as a hopeless case. Furthermore, some of the African countries, including the Sahelian countries Burkina Faso, Chad, and Mali, have all

years—not always consistently over long periods, but progress, nevertheless.

The role of agricultural research in achieving economic and agricultural growth in the Sahel cannot be overestimated. But the problems described above present challenges to research that transcend the conventional technological approaches pursued in Africa over the last 30 years without widespread success. It will be necessary to regroup and reorient scientific resources to solve these problems, with, for example, a broader range of complementary weapons than those used in the Asian Green Revolution[132] and with lower expectations of narrowly technically oriented breakthroughs. The scientific community must seek common cause with the rural community to a much greater extent, in order to achieve a multiplier effect from the wider adoption of a range of less spectacular but hopefully more sustainable techniques.

Joint efforts by researchers and farmers

There are three main areas where agricultural researchers and small farmers must pool their knowledge and use every available new and traditional method in the struggle to increase agricultural growth.

Enhancing soil fertility. Even when yields are very low, as in much of Africa, crop production removes plant nutrients from the soil. Over time, the progressive drain on the soil nutrient bank leads to declining productivity. Continuous cropping can also reduce the organic-matter status of the soil, in particular where annual crops are the main component of the farming system and no organic residues are left in the land. There is no single, and probably no simple, solution to the problem of enhancing soil fertility in sub-Saharan Africa, although its pervasiveness throughout the continent is one of the few issues on which agriculturalists, economists, and policymakers almost universally agree.

Farmers have had to cope with the soil fertility problem long before chemical fertilizers were invented and have been

ingenious in developing ways of doing so. Fallowing[133] is still practiced in some parts of the semi-arid tropics, but in most of the drier areas of the Sahel it is no longer a large-scale option, and in many places it is non-existent. Manuring is an increasingly widespread practice and farmers are well aware of the value of animal manure. However, the crux of the problem here is that most small farmers cannot generate enough animal manure to fertilize all of their land. Research has shown that the amount of pasture and crop residues required to support the livestock is both ecologically and economically unfeasible.[134] In dry areas manure is also used as a substitute for firewood. Composting (a mixture of millet straw and cow dung with added bone meal ashes or rock phosphate) has strikingly beneficial effects in dry years, with up to three times the yields of conventional farming practices, with much greater food security and insurance against crop loss. Composting is also reported to improve soil structure and prevent compaction and water logging. Nitrogen immobility caused by the use of undecomposed straw can occur after the first year, depressing yields, but this can be remedied by mixing the straw with well-rotted animal manure. The main disadvantages of composting are that it is highly labor intensive and requires large quantities of water and that it uses straw needed for animal feed.

Tests have proven that residue management has a significant effect on yields. Mulching with crop residues (straw) plus fertilizer is particularly beneficial in areas where water is not readily available. The main problem here, too, is the competition for the small quantity of straw available. Green manuring (particularly with legumes) is not widely practiced by African farmers. However, incorporating leguminous annual crops into rotations has a number of advantages, including breaking the cereal-disease-pest cycle. Although traditional intercropping practices have tended to decline, there are now signs of renewed interest in combinations like millet and cowpeas, or millet and groundnut.

Much research effort in Africa has been devoted to breeding for crop tolerance to abiotic stress. Farmers, however, do not necessarily welcome these new varieties, because breeders often overlook apparently trivial factors such as keeping quality and

cooking or preparation time. High yield potential is not the be-all and end-all if it means sacrificing some other desired quality. So far, breeding for improved performance in drought or adverse soil conditions has been unsuccessful, although the new maize varieties known as 'super-corn' open up perspectives. Two other less well-known possibilities for improving the soil that have been undergoing trial are the addition of rockphosphate deposits (to add phosphorus) and the use of *Vesicular-Arbuscular Mycorrhizae* (VAM), a beneficial fungus that increases the plant's nutrient uptake.[135] Increasing the efficiency of fertilizer use is also of the utmost importance. This can be done by reducing the costs of its transportation, storage, and delivery. One suggestion has been to use four-wheel-drive vehicles to overcome the poor infrastructure in rural areas, which is seen as a major barrier to the wider use of fertilizer. Also, farmers will have to learn to choose the right input and to apply it correctly for maximum effect at the lowest cost.

The battle against pests and diseases. Insect pests, fungus diseases, viruses, bacteria, and weeds take a heavy toll on plants during growth and on stored plants after harvest. Livestock also suffer from bacterial and viral diseases and parasites. It is probably no exaggeration to say that in farming situations where soils and climate are not the overriding constraints on crop productivity, pests are the single main cause of low yields. In areas where drought or major soil problems also restrict the yield potential, crops are more likely to fall prey to biotic stresses, which compound the effect of abiotic stresses. It is for this reason that about a quarter of agricultural research expenditure has to be devoted to "maintenance research" to safeguard existing yield gains from pest and disease attacks. Research strategy in this field has relied heavily on the development of resistant varieties, but also on chemical controls through pesticides. These solutions have not really been accessible to small farmers in developing countries, however, and that is particularly true of Africa. The limited quantity of pesticides is applied to a few commercial export crops (cotton, tea, and cocoa) rather than food crops.

Farmers have therefore tended to rely on time-honored measures to safeguard their crops: by planting or harvesting

before peak periods of infestation, by planting varieties that tolerate pests or that are unattractive to pests, by varying plant population and density to moderate humidity, by managing fertilizer use to discourage pest build-up, and by avoiding unbroken crop monoculture, which encourages weeds and soil pests. Recent developments have led to a sweeping reappraisal of approaches to control pests and to much greater emphasis on measures that avoid the use of chemicals. They must be regarded as only one weapon in the agricultural armory.

Priority in research is given to the development of alternatives and systems of pest management that integrate the various options in an environmentally benign but effective fashion. The spectrum of measures will include breeding for host plant resistance, where research is being carried out on resistant varieties of wheat, potatoes, maize, pearl millet, sorghum, cooking bananas and plantains, annual legumes, groundnuts, and cowpeas. This is being done partly by conventional plant breeding and partly by biotechnological techniques. Biological control is a technique where the pest's natural enemies are used to destroy them, which can have spectacular results for relatively little expenditure. It has been applied successfully in Africa to combat, for example, the cassava mealybug, the green spider mite, and the mango mealybug.

Integrated pest management is a new ecologically-based approach that integrates the techniques described above. It is based on the concept of an economic threshold, normally determined by the size of the pest population, below which the cost of control measures exceeds the value of losses from pests and weeds. A prime candidate for integrated pest management in Africa would appear to be the parasitic weeds *Striga* and *Alectra*, which have failed to respond to attacks on a single front.

It is unrealistic to expect chemical methods of control to be abolished altogether in the future, but their use is likely to diminish. This puts a premium on research to develop biologically, ecologically, and economically viable alternatives to chemicals, and to improve understanding of how they can be applied more effectively.

People and resources. As discussed in the previous chapter, the poor performance of many donor-funded projects and the lack of sustainability of many donor investments has emphasized the need to involve the people who are supposed to benefit from agricultural development projects. Similarly, the idea of devolving responsibility for the management of forest and irrigation projects from government agencies to local communities is also gaining ground, even though there is frequently a gap between rhetoric and implementation.

Case studies by researchers can highlight the actual experiences of measures that help local people to develop their resources more sustainably in different agro-ecological situations in sub-Saharan Africa. For instance, the response of farmers to the pressure on land use caused by population increase in Kenya has been to switch to more drought-tolerant, shorter-maturing maize varieties, and to use bench terraces and careful husbandry methods to conserve soil moisture. The government supported them by improving the infrastructure, avoiding heavy-handed restrictions on the movement of people, food, and other products. It provided fiscal, price, and marketing policies and tenurial arrangements that gave farmers the incentives to make long-term investments in their land. The government also provided effective and flexible agricultural advisory services offering farmers a menu of technologies to choose from.[136]

In the Siwaa zone in Mali, where environmental degradation has caused over-grazing and deforestation, a technical group was set up that included forestry and livestock agencies and the local authorities. They established a program of land management with the participation of the local people. This has helped to resolve issues such as wood cutting permits and conflicts over grazing lands for livestock. Subsequently, these groups went on to regulate the number and movement of cattle to stop overexploitation of pasture land, to grow forage crops, and to establish a joint research program on herd management, fodder production, and improved management of pasture.[137]

Although it is predicted that the irrigated area in sub-Saharan Africa will increase from five to seven million ha by 2010,[138] this still represents only four percent of the land. Rainfed agricul-

ture will therefore remain of primary importance for most of the region. This puts a premium on measures to conserve rainwater and to use it as effectively as possible. There are three possibilities for soil conservation and water harvesting techniques:

- conservation through tillage to prevent excessive run-off of water, check erosion, and improve filtration;
- harvesting run-off water from sloping lands;
- managing flood plains to achieve better use of floodwater.

All of these need the background of research and case studies to guide future planners and ensure that the people who are intended to benefit are truly involved.

9.3 Constraints to agricultural research

If economic growth and stability in Africa in general, and in the Sahel in particular, depends on agricultural growth, then the role of agricultural research is crucial. However, a recent World Bank strategy paper[139] concluded that "no agricultural research system in Africa is up to present Asian standards, and that only nine systems meet minimum acceptable standards, despite large annual expenditures". According to the same report, all the research institutes were poorly funded, contained research programs with little relevance to agricultural needs, and did not collaborate.

These may well be sweeping statements, but judged in terms of agricultural growth of the main African commodities, the overall performance seems to support these comments.

Nevertheless, some of the success stories in African agriculture were achieved largely because of research. Examples are the adoption of hybrid maize in Kenya, Malawi, Tanzania, and Zimbabwe, the cotton and groundnuts in the Sahelian zone, the tea in Kenya, and the control of the cassava mealybug in the humid tropics. Other successes appear to be the result largely of local initiative drawing on traditional knowledge or commercial enterprise and market signals. There are certainly pervasive (and very

important) problems that remain to be solved. One example is the underutilization of appropriate technologies due to policy and technology transfer restraint. Also, research on natural resource management needs and farming systems needs much more attention relative to research on individual commodities.

The adoption by farmers of new technologies also remains a problem. There has been virtually no small-farmer adoption of improved soil and crop management technologies as recommended by research and extension organizations. Neither have weed control measures been widely accepted, despite the fact that poor soil fertility and weed competition are the two biggest constraints on agricultural productivity.

A question that has often been asked is: do the roots of this pervasive problem lie in the agricultural research systems themselves, in the methods of extending technology to farmers, in government policy and inadequate price incentives, or maybe in the stubbornness of farmers? To an extent all four of these factors contribute to the problem. But farmers can hardly be blamed for rejecting techniques that create labor bottlenecks or imply costs or risks that appear to threaten their livelihood. It is essential to distinguish the availability of technology from its applicability and economic viability.

National agricultural research systems

Certainly, improved performance by the research establishment in Africa could go a very long way to providing the answers. But analysis by the International Service for National Agricultural Research (ISNAR) and elsewhere suggests that there are major problems in these research systems. For example, research institutes are mostly underfunded and have a proportionally large number of young and inexperienced staff. It may now be time for national agricultural research systems to consider slowing down the intake of new young national staff and concentrate on improving the administration and organization of research and on building the capacity of existing staff through training and experience, with stronger financial support.

Politicians do not appear to demonstrate much faith in research as an instrument of progress. African governments provide only about half of the total reported agricultural research expenditure in Africa.[140] Research still heavily depends on donor support, which is limited by Western-style short lending horizons. This weakens the hand of research managers in setting their own priorities and it saps staff morale.

A major problem facing many sub-Saharan African countries is their small size and limited resources. In 1990, 18 countries had a population of less than two million, and another five countries between two and five million. These were mostly in Western Africa. Small size does not necessarily mean small problems: a majority of these countries were in the difficult soil and climate complex of the wet tropics, and most of the remainder were in the driest areas of the continent. It is very difficult for nations of this size to support a research service that can solve the same broad range of problems that besets much larger countries in similar ecological zones.

It is therefore extremely important to find ways of providing these research organizations and institutions with information, know-how, and genetic and other materials that will bridge some of the gaps and dis-economies of scale. This implies closer cooperation among countries, either regionally or sub-regionally, to identify common problems and develop ways of solving them individually or through joint action.

Regional networks

A common strategy to achieve collaborative action is the research network. Theoretically, networks facilitate cooperation among scientists from different institutions in tackling common problems. For example, through regional collaborative research, it may be possible to solve widespread problems such as the control of the parasitic weed *Striga*. And through subregional and ecoregional associations of countries, such as CILSS (see also Chapter 7 and 8) and the Southern African Centre for Cooperation

in Agricultural Research (SACCAR), programs in broader networks had an impact at the country level.

While conceptually valuable, the network approach is being overworked. About 60 agricultural research networks are operating in Africa, and by no means all are working on topics of highest priority. Some national agricultural research systems have reported that providing inputs to several networks puts a heavy burden on them. Some networks are not even headquartered in the region and do not address priority needs. Networks, often encouraged by donors, are not a panacea but a tool to be used with discretion.

Problems in national agricultural research systems

The problems discussed so far have been largely outside the immediate control of the managers of national agricultural research systems. This does not necessarily mean that the systems themselves cannot be blamed for poor performance. At the time of writing, 12 African agricultural research systems have no research master plan, and another eight have only just initiated one. Out of 45 countries, 37 have no consolidated funding mechanism for their system. The eight who do are among the best-managed in the region. Research tends to be overcentralized, with little on-farm or farmer-responsive research. Scientists are therefore often out of touch with demand and farmers' constraints and may develop technology that is unacceptable or of little use to the end user. Ways need to be found to make researchers accountable for the adoption and impact of their work.

Public-sector research may be fragmented. Crop, livestock, forestry, and, sometimes, irrigation research may be located in different departments within ministries of agriculture, or even in different ministries. This hampers effective inter-disciplinary cooperation in priority setting and research. The public-sector research service is also frequently self-contained, with poor linkages to other research sources, including universities, the private sector, and nongovernmental organizations (NGOs). Research findings are often not presented and disseminated in a manner that is

acceptable to staff responsible for extending technology to farmers, or that is understandable by the clients of research. Government information services often lack expertise in modern ways of transmitting information to rural people.

These weaknesses are often compounded by poor linkages and strained relations between researchers and extension staff. One important consequence is that researchers, extension staff, and farmers do not work well together in, for example, socio-economic surveys on the needs and constraints of the rural community, and in on-farm testing of promising research findings. The resulting lack of feedback from the field to research managers and policymakers is a major reason for incorrect targeting of research and inadequate support of research.

Arrangements for monitoring and evaluation of ongoing research and, in particular, of its impact down the line are usually weak or non-existent. This is due partly to lack of trained personnel and appropriate methodology. Attempts by development agencies to build methods for evaluation into projects they support also have a very poor record, although the results could yield valuable information to donors and governments. Monitoring and evaluation should receive much greater attention internationally, particularly with respect to conceptual and methodological issues and to training local staff.

The staff profile of most national agricultural research systems is highly skewed toward genetic improvement and Green-Revolution-style chemical technology. This bias is conditioned to a considerable extent by Western agricultural science approaches and their influence on national staff through overseas training and university curricula. Recent data from the Sahel shows that the situation has changed little from the early 1980s: 48 percent of research effort there goes to crops, 18 percent to livestock production, only nine percent to social sciences, seven percent to soil and water resources, four percent to fisheries, and three percent to forestry and ecology.[141]

Characterization of the environment, understanding of farmers' needs and constraints, and natural resource management are therefore still poor relations of the research priority spectrum. In this situation it should not be surprising that a

majority of the varieties and technical recommendations emanating from the breeders and agronomists either perform below expectations or are rejected by farmers. Genetic improvement may be attractive, but "improved" crops and livestock that do not fit the environment in which they are expected to perform are a waste of staff time and money, and a source of frustration to farmers and disillusionment to governments.

9.4 Solutions

A virtual revolution in research concepts, approaches, and staff composition is required to identify the environmental and socio-economic framework within which new cultivars or techniques are likely to be successful. This turnaround may involve retraining research managers and university staff, and revising curricula to provide the new staff composition, and modern information systems and other supporting services on which successful future innovations will depend.

In order to raise the capacity of national agricultural research systems to carry out effective research in sub-Saharan Africa, countries should propose a master plan for agricultural research. This master plan must identify key priorities and appropriate research strategies, and integrate scientific resources from public- and private-sector research institutions and universities, to plan and implement research. The plan must also define external linkages for information, training, and research collaboration, and specify the financial requirements and consolidate sources of funds within a financial plan for research.

The capacity for policy analysis and for research in the social sciences must be greatly strengthened. Research at the farm or local level is required on key production constraints, on the impact of current government policies on the ability of farmers to resolve those constraints, and on measures to ameliorate them. Policy analysis is needed on factors affecting food demand, consumption, and trade, and on issues related to land tenure, input use, infrastructure, and institutional effectiveness.

Research on the impact of government policies on national research and extension systems is important, but generally neglected. A current hot issue is the impact of structural adjustment and related budgetary cuts on the efficiency of these systems. While privatization is being touted as a solution, private-sector research capacity is low in most African countries, and commercial companies tend to pick out the plums and leave the stones to the public-sector agricultural research systems. The private sector, however, could help in research that can be commercialized by working together with the public sector. Private-sector research institutions could, for example, set aside human resources for, or help funding, research that is commercially interesting for both private- and public-sector research institutions. An advanced field of science such as biotechnology may be an option.

Staff competence must be realigned to meet new research imperatives. The enhanced emphasis on sustainable natural resource management and reduced dependence on chemical inputs have brought about changes in attitudes to agricultural technology. There is an entirely new climate for agricultural research, requiring significant changes in disciplinary approaches. Nowhere are these changes more necessary than in sub-Saharan Africa because of the wide diversity and complexity of resource management problems and the difficulties of implementing Green-Revolution-style technology there. National agricultural research systems should therefore critically review the composition of their current staff and their disciplinary balance. This is also necessary because of the increased emphasis on characterization of the ecological and socio-economic environment within which technology has to be fitted if it is to be acceptable and sustainable. A review might well lead to a move away from conventional plant and animal breeding for high yields toward natural resource management, social sciences, biological pest control, crop diversification, marketing and post-harvest requirements, off-station research, and research on technology transfer and information sciences.

To achieve this move away from conventional research, both long-term and course-related training must be adjusted. There is a need for greater emphasis on management and infor-

mation sciences, as well as on the more conventional scientific disciplines. University curricula must be updated, and, where necessary, academic staff must be retrained to support this effort. A particular effort must be made to develop two-way partnerships between researchers and farmers, both in research planning and conceptualization and in on-farm trials. Farmers should be represented on the boards of research institutes. Researchers should participate in group discussions with communities to understand their wishes and constraints and should be prepared to guide local technical committees.

Linkages between research staff and public- and private-extension and input-supply services must be strengthened. Larger agricultural research systems could establish a technology-transfer unit with staff from research institutions and extension organizations, with strong information support. Smaller systems could station extension liaison staff at research institutions. Greater decentralization of research to ecozonal or other appropriate stations would also help, but outposted staff must be strongly supported by headquarters. Too often out-stations are the orphans of the system.

Bottlenecks in availability of improved seeds and planting material must be eliminated. There is also a need for better availability of other planting material, such as roots and tubers, oilseeds and other cash crops, pasture or other grasses for fodder or soil conservation, and trees for commercial plantations and agroforestry. The public sector and, to an increasing extent, the private sector, should meet these needs, which have been highlighted by several of the 16 international agricultural research centers in the Consultative Group on International Agricultural Research (CGIAR),[142] four[143] of which are headquartered in Africa.

The increasingly complex research agenda is one of several reasons that have underlined the need to strengthen the effectiveness and efficiency of national agricultural research systems. Alliances and collaborative action between international centers in the CGIAR and national agricultural research systems are increasing. The future of agricultural research in sub-Saharan Africa will depend to a large extent on reshaping the national agricultural research systems, with the emphasis on reliable government sup-

port coupled with good training and management. If they are to become effective instruments in bringing about agricultural growth, they will need this as a basis for their pivotal role between the academic researchers on the one hand and the users of technology on the other.

Notes

1 Economic Commission for Africa, *ECA and Africa's Development 1983-2008*. Addis Abeba, 1993.
2 Figures are taken from World Bank, *Social Indicators of Wealth 1994*. (on diskette), Washington, D.C. 1994.
3 On the general problem of population and the prospects for reducing the birth rate, see Leisinger, K.M. and Schmitt, K., *All Our People. Population Policy with a Human Face*. Island Press. Washington, D.C. 1994
4 See World Bank, *World Development Report 1993*. Oxford University Press. Washington, D.C. 1991. Table 26, p.288 ff.
5 Forecasts such as these assume no significant change in the mortality rate (as would occur as a result of the uncontrolled spread of AIDS, for example).
6 See Yudelman, M., *The Sahel and the Environment. The Problem of Desertification*. Published as Leisinger, K.M. and Trappe, P.(eds), *Social Strategies Forschungsberichte*, Vol 4, No. 1. Basel. 1991. p.10
7 See World Bank, *World Tables 1994*. (on diskette), Washington, D.C. 1994.
8 FAO, *State of Food and Agriculture (SOFA), Country Tables 1993*, Rome, July 1993
9 See, for example, OECD, *The Sahel Facing the Future. Increasing Dependence or Structural Transformation. Futures Study of the Sahel Countries 1985-2010*. Paris. 1988.
10 See OECD/CILSS/Club du Sahel, *Development of Rainfed Agriculture in the Sahel. Overview and Prospects*. Paris. 1983.
11 See UNDP, *Human Development Report 1994*. Oxford University Press. New York. 1994. p.131.
12 Ibid. p.133.
13 See FAO, *Production Yearbook 1990*, Vol 44. Rome. 1991. See also FAO, *Food Outlook*. No. 3. Rome. March 1991. p.9.
14 See Giri, J., *Rétrospective de l'économie Sahelienne*. OECD. Paris. 1984. p.10.
15 See, for example, Sasson, A., "Effects of climatic variation on production." In Sasson, A., *Feeding Tomorrow's World*. Sextant Series No. 3. UNESCO/CTA. Paris. 1990. p.235 ff., especially p.272.
16 See FAO, *Production Yearbook 1990*, Vol 44. Rome. 1991.
17 For a detailed discussion of tropical and subtropical climates, see Lauer, W., "Das Klima der Tropen und Subtropen." In Rehm, S. (ed), *Handbuch der Landwirtschaft und Ernährung in den Entwicklungslän-*

dern. Band 3, "Grundlagen des Pflanzenbaues in den Tropen und Subtropen." Verlag Eugen Ulmer. Stuttgart. 1986. pp. 15-45.

18 The Intertropical Convergence Zone is sometimes also abbreviated to ITCZ.

19 See Mensching, H.G., "Die Sahelzone—Probleme ohne Lösung?" In *Die Erde*, Vol. 116. 1985. p.100 ff.

20 See, for example, Lovejoy, P.E., and Baier, T., "The Desert Side Economy of the Central Sudan." In Glantz, M. (ed), *The Politics of Natural Disaster*. Praeger. New York. 1976 p.198 f. See also Somerville, C.M., *Drought and Aid in the Sahel*. Westview Special Studies on Africa. Boulder and London, 1986. And also Sasson, A., "Effects of Climatic Variation on Production. Drought, Desertification and Famine in Sub-Saharan Africa." In Sasson, A., *Feeding Tomorrow's World*. Sextant Series No. 3. UNESCO/CTA. Paris. 1990. p.247 ff.

21 See National Research Council, Board on Science and Technology for International Development (BOSTID), Advisory Committee on the Sahel, *Environmental Challenge in the Sahel*. National Academy Press, Washington, D.C. 1984, and Environmental Change in the Sahel. National Academy Press, Washington, D.C. 1984.

22 Spitteler, G., "Dürren im Air." In *Die Erde*, Vol. 116. 1985. p.177 ff.

23 See Somerville, C.M., Op. Cit. p.1 ff.

24 Sasson, A., Op. cit. pp. 247-248.

25 Ibid. p.250 ff, p.253, and literature cited therein.

26 On this problem, see, among other sources, Sasson, A., Op. cit. pp. 217 and 283 f.

27 For a more detailed treatment of this topic, see Schmidt-Lorenz, R., "Die Böden der Tropen and Subtropen." In Rehm, S. (ed.), *Handbuch der Landwirtschaft und Ernährung in den Entwicklungsländern*. Band 3, "Grundlagen des Pflanzenbaues in den Tropen und Subtropen." Verlag Eugen Ulmer, Stuttgart. 1986. p.47 ff.

28 See especially Von Maydell, H.-J., "Agroforstwirtschaft in den Tropen und Subtropen." In Rehm, S. (ed.), Op. cit. pp. 169-189.

29 See Enquete-Kommission, "Vorsorge zum Schutz der Erdatmosphäre" des Deutschen Bundestages (ed.), *Schutz der Tropenwälder*. Economica-Verlag. Bonn. 1990. p.271 ff.

30 Ibid. p.308 ff.

31 See Riedel, E., "Menschenrechte der dritten Dimension." *Europäische Grundrechte Zeitschrift*. Jg. 16. Heft 1/2. 1989. pp.9-21

32 See Nuscheler, F., "Struktur- und Entwicklungsprobleme Schwarzafrikas." In Nohlen, D. and Nuscheler, F. (eds.), *Handbuch der Dritten Welt*. Band 4, "Westafrika und Zentralafrika, Unterentwicklung und

Entwicklung." Hoffmann und Campe. Hamburg. 1982. Second edition, revised and enlarged. p.12.

33 See also Manshard, W., *Entwicklungsprobleme in den Agrarräumen des tropischen Afrika*. Wissenschaftliche Buchgesellschaft. Darmstadt. 1988. p.87.

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35 IUCN, *The IUCN Sahel Studies*. Gland (Switzerland). 1989. p.84.

36 McNeely, J. and Miller, K. et al., Op. cit.

37 Ibid. p.45.

38 See IUCN, *Review of the Protected Areas System in the Afrotropical Realm*. Gland (Switzerland). 1986. p.94.

39 See IUCN, *The IUCN Sahel Studies*. Gland (Switzerland). 1989.

40 See IUCN, *Review of the Protected Areas System in the Afrotropical Realm*. Gland (Switzerland). 1986. p.124.

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43 See Mensching. H.G., *Desertifikation. Ein weltweites Problem der ökologischen Verwüstung in den Trockengebieten der Erde*. Wissenschaftliche Buchgesellschaft. Darmstadt. 1990. p.3.

44 Ibid. p.4.

45 See also Garduno, M.A., "Technology and desertification." In United Nations Secretariat, *Desertification: Its Causes and Consequences*. Pergamon Press. Oxford. 1977. pp. 319-449. Garduno gives the following explanation (p.320), "Desertification is the impoverishment of arid, semi-arid, and some subhumid ecosystems by the impact of man's activities. It is the process of change in these ecosystems that leads to reduced productivity of desirable plants, alterations in the biomass and in the diversity of life forms, accelerated soil degradation, and increased hazards for human occupancy. Desertification is the result of land abuse."

46 Stebbing, E.P., "The Encroaching Sahara: The Threat to West African Colonies." *Geographical Journal* 85. 1935. pp. 506-524.

47 Aubreville, A., *Climats, Forêts et Désertification de l'Afrique Tropicale*. Sociéte d'Editions Geographiques, Maritime et Coloniales. Paris, 1949.

48 For a new assessment of the problem of desertification, see Rhodes, S.L., "Rethinking Desertification: What Do We Know and What

Have We Learned?" *World Development*, Vol. 19, No. 9. Pergamon Press. Oxford and New York. September 1991. pp.1137-1143.

49 Nelson, R., *Dryland Management. The "Desertification" Problem.* World Bank. Policy Planning and Research Staff, Environment Department. Working Paper No. 8. Washington, D.C. September 1988. Nelson summarizes the problem as follows (p.6): "The point is not to be critical of the questionnaire or the [UNEP] study; given the lack of measurements in the field and the public and political demands for some quantification, what else can be done? The point is to emphasize that the results, which are by far the most widely quoted evidence on the extent of desertification, have an extraordinarily shaky basis and have clearly been enormously influenced in Africa by being completed after a long and exceptionally dry period."

50 See, for example, the conclusions of a study by H.F. Lamprey. *Report on the desert encroachment reconnaissance in Northern Sudan, 21/10—10/11/1975.* UNESCO/UNEP. Paris. 1975.

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52 See Hellden, U., "Drought impact monitoring: A remote sensing study of desertification in Kordofan, Sudan." *Rapporter och Notiser* No. 61. Lunds Universitets Naturgeografiska Institution. Lund (Sweden). November 1984. See also Olsson, L., "An integrated study of desertification. Applications of remote sensing, GIS and spatial models in semi-arid Sudan." *Lund Studies in Geography*. Series C, Vol. 13. 1985. And also Ahlcrona, E., "The impact of climate and man on land transformation in Central Sudan. Applications of remote sensing." *Meddelanden fran Lunds Universitets Geografiska Institutioner*, Avhandlinger, No. 103. 1988.

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54 See, for example, the statement by H.E. Dregne: "Claims that the [desert] is expanding at some horrendous rate are still made despite the absence of evidence to support them. It may have been permissible to say such things ten or twenty years ago when remote sensing was in its infancy and errors could easily be made in extrapolating limited observations. It is unacceptable today." In "Reflections on the PACD." *Desertification Control Bulletin*. Special 10th Anniversary UNCOD Issue. 15 November 1987. p.11.

55 See Hellden, U., Op. cit. Hellden writes (p.53): "There was no creation of long-lasting desert-like conditions during the 1962-1979 period in the area corresponding to the magnitude described by many authors . . . and commonly accepted by the Sudanese Government

and international aid organizations . . . The impact of the Sahelian drought was short-lasting, followed by a fast land production recovery." This example is restricted to a specific and relatively intensely observed area, but it shows the difficulty of determining the extent of desertification and making extrapolations based on local conditions.

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57 World Commission on Environment and Development, *Our Common Future*. Oxford University Press. New York. 1987. pp.127-128. According to *Our Common Future* (p.128), "Land permanently degraded to desert-like conditions continues to grow at an annual rate of 6 million hectares. Each year, 21 million additional hectares provide no economic return because of the spread of desertification. These trends are expected to continue despite some local improvements."

58 Nelson, R., Op. cit.

59 Warren, A. and Agnew, C., *An assessment of desertification and land degradation in arid and semiarid areas*. Paper No. 2. International Institute for Environment and Development. London. November 1988.

60 See, for example, Walker, A.S. and Robinove, C.J., "Annotated Bibliography of Remote-Sensing Methods for Monitoring Desertification." In *Geological Survey Circular* 851. US Department of the Interior. Washington, D.C. 1981.

61 Falloux, F., *Land Information and Remote Sensing for Renewable Resources Management in Sub-Saharan Africa*. World Bank Technical Paper No. 108. Washington, D.C. 1989.

62 Ibid. p.8.

63 See National Research Council, Advisory Committee on the Sahel, Board on Science and Technology for International Development (BOSTID), Office of International Affairs, *Resource Management for Arid and Semiarid Regions: Environmental Change in the West African Sahel*. National Academy Press. Washington, D.C. 1984.

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World Bank. Washington, D.C. 1986. See also Enquete-Kommission, Op. cit.

65 See the detailed list provided in Manshard, W., Op. cit. pp.192-199.

66 See Poupon, H. and Bille, J.C., "Recherches écologiques sur une savanne Sahélienne du Ferlo septentrional, Senegal: Influence de la secheresse des l'années 1972-1973 sur la strate ligneuse." In *La Terre et la Vie* No. 28. 1974. pp 49-75.

67 Ibid.

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69 *Wadi* is a geographical term for a deep and usually dry desert river bed.

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74 See Allen, J. (ed.), *The Sahara. Ecological Change and Early Economic History*. The Centre of African Studies of the University of London. London. 1978.

75 See Sandford, St., *Management of Pastoral Development in the Third World*. John Wiley & Sons. New York. 1983. See also Yudelman, M., *Prospects for Agricultural Development in Sub-Saharan Africa*. Occasional Paper. Winrock International Institute for Agricultural Development. Morrilton, Arkansas. 1987.

76 Stryker, J.D., Op. cit.

77 See IUCN, *Review of the Protected Areas System in the Afrotropical Realm*. Gland (Switzerland). p.147.

78 See Food and Agriculture Organization (FAO), *Review of the Tropical Forestry Action Plan (TFAP). A Report by a High Level Independent Mission*. Rome. 1990.

79 See Side, Gaye, "Glaciers in the Desert." *Ambio*, Vol. 16, No. 6. pp.351-356.

80 See Club du Sahel, *Forestry and Ecology Development in the Sahel. Overview and Prospects*. OECD. Paris. 1983.

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82 See Bremm-Gerhards, U., "Chancen solarer Kochkisten als angepasste Technologie in Entwicklungsländern." Published as: *Sozialwissenschaftliche Studien zu Internationalen Problemen*, No. 165. Breitenbach Publishers, Saarbrücken and Fort Lauderdale. 1991.

83 See Baldwin, S. et al., "Improved Woodburning Cookstoves. Signs of Success." *Ambio*, Vol. 14, No. 4-5. pp.280-287.

84 See Lal, R., *Soil Erosion problems on Alfisols in Western Nigeria and their control.* IITA Monograph. Ibadan, Nigeria. 1986.

85 This chapter was written by Ms. Gudrun Graichen-Drück. It appeared previously in Donner-Reichle, C. and Klemp, L. (eds.), "Frauenwort für Menschenrechte. Beiträge zur entwicklungspolitischen Diskussion." *Sozialwissenschaftliche Studien zu internationalen Problemen* Nr. 146. Breitenbach Verlag, Saarbrücken and Fort Lauderdale. 1990. Some editorial changes have been made in the present version. We extend sincere thanks to Breitenbach Verlag for their kind permission to reprint this article.

86 Monimart, M., *Femmes et Lutte contre la Désertification au Sahel. Etude d'Expériences dans six pays.* Ouagadougou. June 1988. Marie Monimart interviewed women in Burkina Faso, Cape Verde, Mali, Mauritania, Niger and Senegal. Her survey contains an abundance of very vivid statements by Sahelian women. Translated from French by the author.

87 Ibid. p.16.

88 Ibid. p.21.

89 Ibid. p.19.

90 Ibid. p.18.

91 Ibid. p.19

92 Ibid. p.30

93 Ibid. p.31.

94 See Schörry-Klinger, *Zielgruppenanalyse der Frauen. Integrierte ländliche Entwicklung.* Achram Diouk, Mauretanien. Graue Literatur für GTZ. June 1988. pp.8 f.; 36 f.

95 Monimart, M. Op. cit. p.24.

96 Ibid. p.28.

97 For statements on family structure, see Monimart, M. Op. cit. p.25 ff.

98 Ibid. p.132.

99 Ibid. p.130 f.

100 Ibid. p.9.

101 Ibid. p.33.

102 Spitteler, G., *Handeln in einer Hungerkrise. Tuaregnomaden und die grosse Dürre von 1984.* Opladen. 1989. p.94 ff.

103 See Broetz, G., "Ihr könnt uns nicht den Regen bringen." In *Modernisierung der Ungleichheit. Beiträge zur feministischen Theorie und Praxis* Nr. 23. 1988. pp.41-52.

104 Rochette, R.M. (ed.), *Le Sahel en Lutte contre la Désertification. Leçons d'Expériences.* CILSS/GTZ. Weikersheim. 1989. (The impression is

given that the achievements of women were acknowledged above all in the case studies where a woman was one of the authors, although this gender-specific perception does not hold true throughout).

105 All examples are taken from Burkina Faso. See Rochette, R.M., Op. cit. pp.236, 295, 331 f. and 346 ff.

106 Rochette, R.M., Op. cit. p.196.

107 Ibid.

108 Family planning programs, for example, are usually not founded on the rights of self-determination for women. Instead, they are justified as measures to protect scarce natural resources, since women will be able to perform their tasks only if they have fewer children to mind.

109 One such example is that provided by my esteemed teacher, K. William Kapp, who wrote *The Social Cost of Private Enterprise* (Harvard University Press, Cambridge, Mass.) as early as 1950!

110 See Meadows, D. et al., *The Limits to Growth: A Report to the Club of Rome*. Club of Rome. 1972.

111 Mesarevic, M. and Pestel, E., *Mankind at the Turning Point: The Second Report to the Club of Rome*. Club of Rome. 1974.

112 Council on Environmental Quality and Department of State, *The Global 2000 Report to the President. Entering the Twenty-First Century*. Charlottesville. 1991.

113 World Commission on Environment and Development, *Our Common Future*. Oxford University Press. New York. 1987.

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115 See Club du Sahel/CILSS, *Forestry and Ecology Development in the Sahel*. OECD. Paris. July 1983. p.5.

116 See OECD, *Development Co-operation, 1990 Report*. Paris. 1990. p.224.

117 See Somerville, C.M., Op. cit. p.221.

118 Office of Technology Assessment (OTA), *Continuing the Commitment: Agricultural Development in the Sahel*. Special Report, OTA-F-308. US Government Printing Office. Washington, D.C. 1986. p.56.

119 See Club du Sahel and CILSS, *Development of Rainfed Agriculture in the Sahel*. OECD. Paris. July 1983. p.6.

120 Ibid. p.7.

121 See Direktion für Entwicklungszusammenarbeit und Humanitäre Hilfe (publisher), *Entwicklungszusammenarbeit der Schweizerischen Eidgenossenschaft. Jahresbericht 1990*. Bern. 1991.

122 See Lal, R., Op. cit.

123 See Anderson, D., *The Economics of Afforestation*. Johns Hopkins University Press. Baltimore. 1987. See also Club du Sahel, *Ecology and*

Rural Development in Subsaharan Africa: Selected Case Studies. OECD. Paris. 1988.

124 See Direktion für Entwicklungszusammenarbeit und Humanitäre Hilfe, Op. cit. p.6.

125 Schneider, B., *Die Revolution der Barfüssigen*. Europa-Verlag. Zürich. 1986.

126 See Drabet, A.G., "Development Alternatives. The Challenge for NGOs. An Overview of the Issues." In *World Development* 15, Supplement 1987, ix-xv. See also InterACTION, "NGO Statement Submitted to the 509th Meeting of The Development Assistance Committee." In *Monday Developments*. 23 June 1986.

127 See Schneider, B., Op. cit. p.239 ff.

128 See Club du Sahel, *Ecology and Rural Development in Sub-Saharan Africa*. Selected Case Studies. Op. cit.

129 Sub-Saharan Africa comprises all of Africa south of the Sahara and includes the Sahel and the islands. The term is generally used to draw a border between the Arab countries in the north (Morocco, Algeria, Tunisia, Libya, and Egypt) and the rest of the continent.

130 See *FAO Production Yearbook*. Vol. 47. Food and Agriculture Organization of the United Nations. Rome. 1993. Table 3, Population.

131 A national agricultural research system comprises all a country's entities responsible for organizing, coordinating, or executing research that contributes directly to the development of its agriculture and the maintenance of its natural resource base. Agriculture is understood to include the production of fish and trees, as well as crops and livestock. A national agricultural research system might include, for example, public-sector research institutes, agricultural universities, research departments within ministeries of agriculture, and organizations that do research on forestry or fisheries.

132 In Asia, the use of technology-improved crop varieties that depend on high levels of external inputs (such as water, fertilizer, and plant protection chemicals) has produced impressive and sustained increases in yields in many parts of the continent. This is referred to as the Green Revolution.

133 Fallowing is the practice of leaving previously tilled land untilled for (part of) the growing season or longer to allow the natural fertility of the land to be restored.

134 See Speirs, M. and Olsen, O. *Indigenous Integrated Farming Systems in the Sahel*. World Bank Technical Paper 179, Africa Technical Department Series. The World Bank. Washington, DC. 1992.

135 Because phosphate deficiency is widespread in African soils, the World Bank is considering a major campaign to access natural rock phosphate deposits and distribute the ground materials to farmers.

136 See Tiffen, M., Mortimore, M., and Gichuki, F. *More people, less erosion. Environmental recovery in Kenya.* John Wiley and Sons. Chichester. 1994.

137 See Joldersma, R. and Negueba, F., "The SIWAA experience: Village land management in Southern Mali." in *ILEIA Newsletter for low external input and sustainable agriculture.* Vol. 10, Nr. 2. July 1994. The Netherlands.

138 See *Agriculture Towards 2010.* Conference Document C93/24. Food and Agriculture Organization of the United Nation. Rome. November 1993. Table 415.

139 See Cleaver, K.M., *A strategy to develop agriculture in sub-Saharan Africa and a focus for the World Bank.* World Bank Technical Paper 203. Africa Technical Department Series. World Bank. Washington, DC. 1993

140 According to figures obtained from the ISNAR Indicator Series project.

141 See Weijenberg, J., Dioné, J., Fuchs-Carsch, M., Keré, A., and Lefort, J. *Revitalizing Agricultural Research in the Sahel.* World Bank Discussion Paper 211. Africa Department Technical Series. World Bank. Washington, DC, 1993.

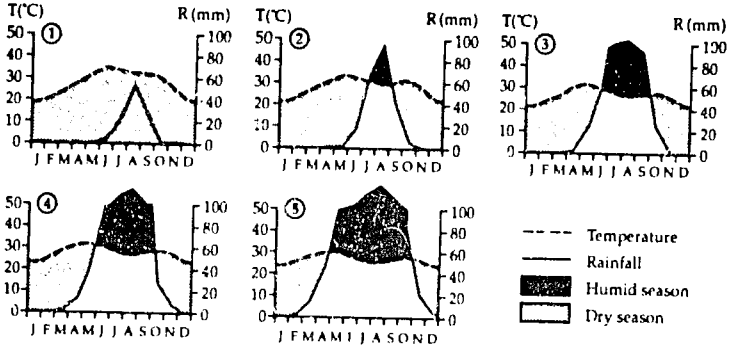
142 Established in 1980, ISNAR is a member of the CGIAR.

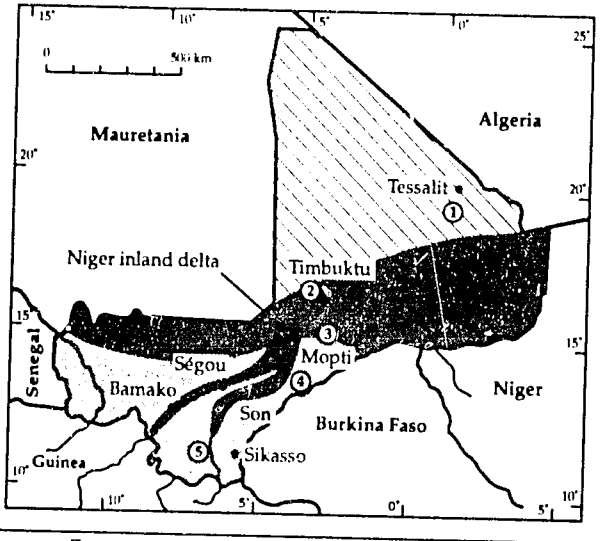
143 West Africa Rice Development Association (WARDA)—Côte d'Ivoire
International Institute of Tropical Agriculture (IITA)—Nigeria
International Centre for Research in Agroforestry (ICRAF)—Kenya
International Livestock Research Institute (ILRI)—Kenya and Ethiopia

II Mali: A Typical Sahelian Country

Figure 5

Mali's climate zones





Zone	Annual rainfall	Dry months
Desert	< 200 mm	11–12
Sahel	200–700 mm	8–11
Dry savanna	700–1100 mm	5–8
Humid savanna	1100–1500 mm	2–5

Source: B. Messerli, Geographic Institute of the University of Berne, Switzerland

1 Geography and Ethnic Composition

Mali is a landlocked country with a total area of 1.24 million sq km. The longest distance between the southermost point and the northernmost point is 1,600 km. It stretches from the sandstone plateaus in the southwest (200–400 m above sea level) across the lowland plain of the Niger River to the Adrar des Ifores massif (700 m above sea level) in the northeast.

From the humid savanna to the rocky and sandy desert, the country's landscapes include a great variety of biotopes. Cultivation conditions are very favorable in the humid southern regions, while only nomadic pastoralism is possible in the dry northern part of the country. The Niger and the Senegal River systems, the two major rivers in Mali, are of key importance to the entire country (see Figure 5). They enable intensive irrigation and they are good fishing waters as well as important transport routes.

The Bambara and the Malinke are the main groups of Mali's population today. Their languages, Bamanakan and Maninkakan, are closely related dialects spoken by about 50 percent of the country's approximately 8.6 million inhabitants. A further 25 percent can understand these two languages. Bamanakan has developed into the lingua franca of Mali. The more simply structured Dyula dialect (derived from Bamanakan) is understood in Senegal, Gambia, and from Guinea across the northern parts of Côte d'Ivoire, Burkina Faso, and northern Ghana. This wide dispersion of a common language can be traced back to the ancient Kingdom of Mali.

Other ethnic groups include the Bozo and Somono (who fish along the Niger), the Soninke (who practice agriculture and engage in trade in the northwest), and the Kasonke in the western part of the country.

Songhai, a language unrelated to any other in sub-Saharan Africa, is the major language in the northeastern part of the country, from Lake Débo to Gao, and in the Republic of Niger.

About six percent of Mali's population speaks Songhai. Less than about five percent of the population speaks Tamashak, the language of the Tuareg people, and Arabic. The Bwa and the Bobo, who practice agriculture, and the pastoralist Peul account for about 17 percent of the population. Their language, Fulfulde, is related to Wolof and Tukulor, which are widely spoken in Senegal. Dogon, Senufo (or Minianka), and Samo, spoken by not more than 12 percent of the population, belong to the Voltaic or Gur branch of languages.

Mali is a large country, about the size of Germany, France, the United Kingdom, Belgium, and the Netherlands combined. Its ethnic composition is fairly homogeneous compared with most sub-Saharan African countries. However, since Mali's different ethnic groups do not live together in large numbers but in groups or clans in village "quarters"—as the Malians say—the situation becomes more complex. Social hierarchy also plays a significant role; it further classifies individuals into social categories within the same language group.

The ethnic composition in the inland delta of the Niger River illustrates this situation. Here, most villages are bilingual, if not trilingual. In school, French is taught as a fourth language. The inland delta of the Niger (the old province of Massina) begins east of Ségou and is bordered on the east by Lake Débo. In between are broad river valleys and flood plains, which are a little larger than half the size of Switzerland when the Niger and its most important tributary, the Bani, are at peak flood stage.

The water in this area traditionally belongs to the Bozo and the Somono, the soil to the Maraka, and the grass to the Peul. The Bozo are linguistically related to the Soninke, the Bambara, and the Malinke. They are the oldest inhabitants of Massina. The word Bozo itself is a Bambara term used to designate outsiders. The Bozo divide themselves into four subgroups, who can only partially understand each other. Originally, the four groups engaged in fishing with different types of fishing equipment and inhabited different water courses of the Niger and Bani River systems.

The Somono probably descend from a mixture between Islamic Bozo and Bambara peoples. They live primarily from fishing, but they also cultivate rice, although the Bozo do not.

Today *pirogues* (traditional wooden boats) are still built exclusively by Bozo craftsmen, never by the Somono. The Somono speak the Bambara language in the Ségou area and, in the Mopti region, one of the four Bozo dialects. They are the most important *pirogue* owners and providers of river transport. The Bozo and the Somono do not live together in the same village, nor do they intermarry. To make matters even more complicated, some Bozo and Somono families of older lineage are considered to be nobles, while other families are regarded as serfs. These social differences have nothing to do with wealth; they relate only to rights and behavioral patterns.

Maraka, which means "one who rules," is the Bambara word for the Soninke. The Maraka regard themselves as a kind of aristocrats, whose origins can be found in the medieval Kingdom of Ghana. However, several classes developed within this group throughout the course of history. Only the *maraka pi*, or "black Maraka," are regarded as the actual descendants of the Soninke. It is said that the others became Maraka only at a later time—in some cases just prior to Mali's independence in 1960—when they converted to Islam, began to wear *boubous* (robes), and became merchants.

The Peul are an even more complex case. They are divided into at least seven different subgroups, each of which has a very specific place in their social hierarchy. At the top are the actual Peul, who call themselves Fulbe. The Fulbe constitute about 50–60 percent of the Fulfulde-speaking population. They are *dimo* ("noble"). The distinction *dimo* also goes for the Jaawambe, a very small, respected, if not feared, minority. The Jaawambe are considered to be clever and shrewd; many leading merchants are Jaawambe. Next in the hierarchical order are the Nyeenybe, who are craftsmen (weavers, potters, gold- and silversmiths, leather- and woodworkers) and account for about eight percent of the population. Intermarriage among Nyeenybe, Fulbe and Jaawambe has traditionally been strictly taboo. At the bottom of the hierarchy are two categories of "bondsmen", the Rimbe, whose ancestors were slaves of the Fulbe.

Society and hierarchy

These social differences and hierarchical structures are very confusing for an outsider. The Bambara and the Malinke would say that they can be traced back to Sunjata, the founder of the medieval Kingdom of Mali and a cultural hero of the Republic of Mali. It was Sunjata who divided up the world in this manner in the 13th century. From the Peul's point of view it has always been this way.

In none of the country's ethnic groups does social hierarchy have to do anything with possession, however. It is exclusively a question of aristocracy and nobility, and closely connected with family names and with rules of conduct that are to be observed in daily life.

Family names, called jamu by the Bambara and the Malinke and *yettoore* by the Peul, can be interpreted easily by experts. Most people in Mali have specific family names that are derived from the names of their fathers (patronymics) and that classify them in ethnic and sociological categories. For example, "Diarra" and "Coulibaly" are the names of the two royal dynasties of the Kingdom of Ghana, while "Diallo," "Ba," "Bari," and "Cissé" are noble Peul patronymics.

Even today, conversations among close friends living in the same village often touch on questions of origin—not only the origins of human life, but above all the origins of the different "races." The French word *race*, which has an equivalent in all Malian languages, is usually used to refer to as *jamu* or *yettoore*, i.e. the patronymic.

"I ye shiya jumin ye?" "What 'race' (*shiya*) are you?," people of Mali often ask each other. The answer is not "Bambara," for example, but *"numu"* (smith), *"horon"* (noble) or *"kule"* (woodworker). Membership of an ethnic group or a social class and of a specific clan determines social behavior, possible marriage arrangements, and even access to resources.

Of course, time has not stood still. Many influences, primarily of Western origin, have considerably changed and partly remolded Mali and its people. The system of social hierarchies and relationships sketched above, described by many authors as

a "caste" system, is disintegrating in the country's major cities. But in hundreds, perhaps even thousands, of villages the significance of the social categories has remained unchanged. This is one of the reasons why so many young people abandon rural life, to seek a new (if often miserable) life in the city, free from social obligations.

2 The Economy[1]

With a per capita gross domestic product (GDP) of US $298, Mali is one of the world's poorest and least developed countries.[2] It has few mineral resources (bauxite, iron ore, manganese, uranium) and a very small industrial sector that accounts for 14 percent of the country's GDP. More than 80 percent of the work force is engaged in agriculture, which accounts for 45 percent of GDP. This GDP percentage can vary significantly from year to year because agricultural production is highly dependent on the region's uncertain climatic conditions. In 1988 and 1989 Mali produced grain surpluses thanks to exceptionally good weather conditions. In many previous years entire harvests were ruined by drought.[3]

Between 40 and 80 percent of Mali's livestock perished in the 1983–85 drought, and the grain harvest dropped by an estimated 300,000 tons in 1984. One-third of the population of seven million at that time suffered from the effects of famine, and five percent were faced with possible starvation.[4] But poor climatic conditions and problems related to desertification (see also Part I, Chapter 6.3) are not the only reasons for low agricultural output. Political and institutional neglect of the agricultural sector and low producer prices also play a role.

An exporter of raw materials (cotton, groundnuts, cattle, skins, pelts, dried fish, rice, gold, and rubber), Mali saw its terms of trade index fell dramatically during the 1970s and early 1980s. In 1986 it stood at 75 (1980 = 100), rose to 87 in 1991, but dropped again to 74 in 1992. One effect of the resulting chronic budget deficits was that public-sector employees went without their salaries for months. There were large foreign-trade deficits and the service sector also showed a negative balance sheet. High net workers' remittances from neighboring countries, especially Côte d'Ivoire (US $91 million) and official development aid receipts (US $414 million) improved the balance of payments. Total external debt exceeded US $2.5 billion, with over 95 percent being long-term public and publicly guaranteed debt.[5]

Cotton is Mali's most important export crop and is cultivated primarily in the south. Cotton production grew significantly in Mali during the 1980s, as it did in many other African countries. Production rose from 48,000 tons in 1979–81 to 97,000 tons in 1989–90 and 114,000 tons in 1992.[6] However, cotton prices dropped by 50 percent in 1985–86, but prices soon recovered. Mali had export earnings of US $195 million from cotton alone in 1991.[7]

Because weather conditions were favorable, earnings from cereals were also good in 1989–91. But government price policy, biased toward urban interests instead of providing incentives to farmers, makes cereal production so unprofitable that many producers switch to cotton. Unless political reforms are instituted, Mali will not be in a position to become self-sufficient even in favorable climatic conditions.

Table 7 (cont'd on next page)

Key data on Mali (as at 1992)	
Geography / Demography	
Area	1,240,190 sq km
Population	9.0 million[a]
Population density	7 people/sq km
Urban population (as percentage of total population)	25.1%[a]
Average annual population growth 1980–92	2.6%[b]
Ethnic groups	Bambara, Malinke, Songhai, Senufo, Peul-Fulani, Dogon, Tuareg (approx. 10% nomads)
Official language	French
Languages spoken	Bambara, Arabic, others
Religion	Muslim (90%) , animist (9%), Christian (1%)
Social Indicators	
Adult illiteracy (1990)	68% (women: 76%)[a]
Primary education (1991)	25% (women: 19%)[a]
Life expectancy at birth	48.4 years (women: 51.9 years)[a]
Infant mortality rate (per 1,000 live births)	30.0[a]
Population per physician	1 physician per 19,448[a]
Average daily calory supply per person (1988–90)	2,260 (Switzerland: 3,437)[c]
Energy consumption per capita	24 kg of oil equivalent (Switzerland: 4,193)[a]
Economic Indicators	
Gross domestic product (GDP)	US $2,667 million[d]
- agriculture	44.9%[d]
- industry	13.7%[d]
GDP per capita	US $298[d]
Average annual GDP growth 1980–92	2.9%[b]
Annual inflation rate 1980–92	3.7%[b]
Labor force	3.13 million (women: 15.9%)[d]
Informal sector as percentage of total economic activity	50% (estimate)
Net workers' remittances	US $91 million[d]

Table 7 (cont'd)

Foreign Trade[a]

Exports	US $388 million
Main products	gold, cotton, live animals, vegetative oil
Imports	US $740 million

	Exports	*Imports*
Non-fuel primary products (incl. food)	91.8%	21%
Fuels	0%	30%
Manufacturing	8.2%	49%
Total	100%	100%

Other[a]

Terms of Trade (1980 = 100)	73.7
Gross international reserves	US $308 million
Total external debt	US $2,595 million
- as percentage of exports	350.7
- as percentage of total GDP	97.3
Official development assistance receipts	US $414 million

Sources:
[a] World Bank, *Social Indicators of Wealth 1994*. (on diskette), Washington, D.C., 1994.
[b] World Bank, *World Development Report 1994*. Washington, D.C. 1994.
[c] United Nations Development Programme, *Human Development Report 1994*. Oxford University Press, New York, 1994
[d] World Bank, *World Tables 1994*. (on diskette), Washington, D.C. 1994.

3 The Political Situation

Mali at the end of the Second Republic

Following the dramatic political changes in Eastern Europe in the early 1990s, many African nations also rid themselves of despots. One of these nations was Mali, where a military coup toppled the Second Republic on 26 March 1991. Today Mali is governed by one-time civilian opponents of the former regime.

Until very recently Mali was considered one of the poorest but politically most stable countries in sub-Saharan Africa. The Second Republic was established in 1968 when a military coup overthrew the country's first president, Modibo Keita. Lieutenant Moussa Traoré became head of state, general and supreme commander of the army, and chairman of the Union Démocratique du Peuple Malien (UDPM), the country's only political party.

Traoré eventually developed into an autocratic symbol of nationhood and used the army to help him unite a country with more than 20 ethnic groups and six languages. He became known internationally as Chairman of the OAU (Organization of African Unity), as the initiator of the Bamako Initiative, which is named for the country's capital and is concerned with making basic medicine more affordable and more available in Africa, and as co-president of the United Nations World Summit for Children.

Burdened with debt, Mali got deeper into crisis during the 1980s. Contributing factors included recurrent droughts, desertification, chronic grasshopper plagues, and a worsening of its terms of trade. But Mali's problems are also due to the disastrous effects of a planned economy, in particular on the main staples sorghum, millet, and rice. Additional factors were capital flight, political nepotism in the bloated and inflexible government machinery, corruption, and gross mismanagement. Well over one million people emigrated as foreign workers, most of them to Ivory Coast and France, Mali's former colonial ruler.

France, along with Switzerland, Germany, the Netherlands, the USA, and other countries, as well as multilateral organi-

zations such as the United Nations Development Programme (UNDP), have all given, and continue to give, considerable financial and technical development aid. They also provide low-interest loans and grants. German and Swiss public and private donors have designated Mali for priority development aid. While Mali was virtually unknown in these countries (people typically confused it with Bali, a well-known island in Indonesia), intensified development cooperation efforts have brought Mali to the attention of a large international audience.

In 1981 the government began liberalizing the cereals trade, dissolved deficit-ridden government and parastatal industries (including the national airline, Air Mali), and streamlined the bureaucracy. Although these measures, along with an exceptionally good harvest, improved the economic situation in 1989, political problems remained unresolved. Persistent ethnic strife in the north of the country continues, and in recent years Malian police have had regular armed clashes with Tuareg nomads.

The capital Bamako is a troubled city, with a population growing at double the rate of the rural population and soon to reach one million. There is no adequate infrastructure to support this dramatic growth and no financial resources for badly needed investments. There are shortages of virtually all basic necessities, in particular housing, sewage systems, and water. Many of the younger generation are unemployed; most of them have had no proper schooling, and the private sector is not large enough to replace the state as the country's main employer. State employees have been known to be without any income for as long as six months. Dissatisfaction is spreading, promoted by the rampant nepotism and corruption.

Nevertheless, in the past decade, local development efforts and international development aid have brought about some improvements, especially in water supply, the forestry and agricultural sectors (sorghum, millet, and cotton), the construction of more roads and streets, the transport sector, and telecommunications. "Associations villageoises" (village associations), which were founded as a form of institution building on established traditions throughout the country, are beginning to gain a foothold. Agriculture, which accounts for 85 percent of the work force

and 97 percent of the country's exports (mainly cotton, groundnuts, and cattle), is making slow progress. It continues to depend heavily on favorable weather conditions.

Food production cannot keep pace with the country's population growth rate (2.6 percent per year in 1980–92), although the United Nations Food and Agriculture Organization (FAO) maintains that available resources, aided by modern technology, could feed the country's population up to four times.

In these circumstances, it is no surprise that opposition to the Traoré regime intensified in late 1990, especially in the capital. The government made some concessions—too few and too late, as it turned out—including greater freedom of the press and the introduction of a multi-party system *within* the UDPM government party. The opposition organized itself in two groups: the Comité National d'Initiative Démocratique (CNID—a national committee to promote democracy, mainly politicians from the First Republic) and the Association pour la Démocratie au Mali (ADEMA).

School children and university students took to the streets to protest the lack of funds for education, and unions, in a show of solidarity, organized a general strike. Demonstrators numbered in the tens of thousands. Shops and homes were plundered in the process.

At the height of these demonstrations soldiers fired into the crowd; almost 200 people were killed in the ensuing turmoil, many more were wounded, and damage ran into millions of dollars. Public demands were made for the president to resign, but he refused. On the evening of March 25, 1991, a group of young paratroopers staged a coup. The president and his wife were arrested by the commander, Lieutenant Colonel Amadou Toumani Touré. The Comité Transitoire pour le Salut du Peuple (CTSP) assumed power under his leadership.

The CTSP consisted of 11 military officers and 15 former opposition leaders. It was to serve as an administrative authority until the parliamentary and presidential elections that were promised. The CTSP installed a new government of politically acceptable experts under the leadership of Soumana Sacko, a former finance minister with a reputation for integrity, who had

been dismissed by the previous government for his uncompromising struggle against corruption. All former ministers and generals were deposed and the UDPM was dissolved. Privatization was encouraged. The CTSP promised to honor agreements with foreign countries, guaranteed human rights, and abolished the requirement for a visa to travel abroad.

Foreign countries, including mainly France and the USA, reacted swiftly and positively. Suspended development aid was reinstated and even increased, and the transitional government enjoyed the trust of donor countries.

The CTSP also established a national council to draw up a new constitution. A multi-party system was encouraged, and within weeks 32 parties were officially registered. ADEMA was the main winner in the elections, held on February 23 and March 8, 1992. It now holds the majority in parliament. At the end of April 1992, Alpha Oumar Konaré, a 46-year-old former archeologist and historian, was elected president in a second round of voting. He is the first democratically elected president of Mali.

Exceptionally good rainfall in 1994, resulting in record cotton and groundnut yields, combined with booming export prices, have helped the economy to recover from the effects of the 50-percent devaluation of the FCFA.

Student revolts, which plagued the country in previous years, have subsided. What prevents Mali from benefiting even more from the prevailing beneficial conditions is the ongoing skirmishes between groups of Tuaregs and the army. These clashes make the entire north unsafe and cause parts of the population to take refuge in calmer regions. As matters stand now, one can only hope that the current peace negotiations will be successful.

4 Environmental and Sociopolitical Problems

4.1 Issues to be solved

Although Mali's environmental and sociopolitical issues are not unique to sub-Saharan Africa, together they illustrate the complexity and interrelationship of the kind of problems that one country alone must try to overcome.

Population growth

Most Malians, as most people in developing countries, wish for as many children as possible. This wish is influenced not only by tradition, religion, and thought and behavior patterns, but also by high child and infant mortality rates.

Mali's high population growth rate is putting increasing pressure on the country's scarce natural resources. This has had serious consequences for the country's economy, social structure, and environment.[8] Already, Mali is unable to satisfy its own food requirements, except in climatically and economically good years. As long as birth rates remains high, sustainable self-sufficiency (to say nothing of the need for sound natural resource management) will be increasingly difficult to achieve.

Urbanization

Urban populations in developing countries are growing more rapidly than the overall population in these countries (see also Part I, chapter 3.4). As Mali's urban areas are growing at about 5.2 percent per year, it is becoming increasingly difficult for the authorities to supply basic services such as drinking water, electricity, suitable housing, sanitation, sewage, and garbage disposal services. An increasing volume of traffic and a large number

of charcoal and wood-burning stoves are causing heavy air pollution in cities and can reach levels hazardous to health, in particular in the capital, Bamako. Since there is a minimum of local resources available to finance development in Mali, no substantial investments to upgrade the urban infrastructure are likely to be made in the near future. Neither are there sufficient financial resources for appropriate rural and agricultural development measures to put a stop to or slow down the rural exodus.

Poverty-related diseases

Public health in Mali is generally poor and mortality rates are high, especially among young children (see Table 8). Poverty and disease form a vicious circle that is very difficult to break. The lower the level of a country's social and economic development, the greater the number of its people living in poverty, and the greater the number of those who are unable to satisfy basic needs. This results in higher mortality and increased spread of disease. Economic development cannot take place where the population is in poor health.

Table 8

Health profile for Mali	
Births attended by medical staff (1985–90)	14%[a]
Babies with low birth weight (1985–90)	10%[a]
Children (under age 5) suffering from malnutrition (1990)	25.1%[b]
Mortality rate per 1,000 live births (children under age 5; 1992)	201.1[b]
Percentage of population with access to health services (1985–91)	35%[a]
Population per physician	19,448[b]
Public expenditure on health (as percentage of GDP; 1990)	2.8[a]

Sources:
[a] UNDP, *Human Development Report 1994. Oxford University Press, New York. 1994*
[b] World Bank, *Social Indicators of Development*, Washington, D.C. 1994

Lack of clean water is one of the primary factors in the spread of infectious diseases. Many of the traditional water sources in Mali are open wells that often contain polluted surface water mixed with sewage. Although it is unfit for human consumption, the water has to be used because it is the only water available. Inadequate sanitation and poor waste disposal practices provide ideal breeding conditions for disease transmitting vermin, and encourage additional focuses of disease to develop. The flood plain of the Niger delta is a breeding ground for snails that carry schistosomiasis and for insects that transmit river blindness and malaria.

Agriculture

In Mali, as in other Sahelian countries, agricultural productivity is very low and agriculture provides little income. In general, land is the common property of a group (family, village, or ethnic group) and is assigned for individual use according to fixed rules. The advantage of this is that the pressing problem of landlessness and of poor landless groups of people is not as great in Mali as in, for example, Asia. But the disadvantages of these land-use rights are considerable, such as a lack of collateral for credits or the hazards of overuse of commonly owned land. There is a shortage of agricultural inputs, and modern agricultural tools and techniques are not widely available (this applies only to the traditional agricultural sector, not to export crops). Most farmers receive neither incentives nor the financial means to invest in soil conservation techniques. The resulting erosion causes soil degradation and rapid destabilization.

Drought

Drought, as mentioned earlier, is a natural phenomenon and therefore beyond human control. It is one of the Sahel's most serious problems and affects all the countries in the region. It poses a tremendous obstacle to agriculture and those who depend on agriculture. Even in the foreseeable future drought seems

impossible to avoid. Infrastructural measures and better planning could reduce both the known and the expected impacts of recurring drought a great deal, but these measures are not carried out to the extent they should be. Better planning for future needs and more appropriate patterns of use with regard to scarce land and water resources could help considerably in preventing these resources from being totally exhausted.

Migration

Migration to Mali's more humid southern region has been a traditional strategy for avoiding drought. Here the climate is more favorable and the soil more fertile. But the southern areas of the country cannot accept unlimited numbers of migrants without jeopardizing the natural limits of resource overuse, thus sparking a new spiral of problems.

Deforestation

Extensive deforestation to obtain firewood and timber, without adequate reforestation programs, is an explosive problem in Mali. In many cases it has led to complete destruction of forests. Since firewood is the country's central source of energy (it supplies about 90 percent of all energy in Mali), and because no alternatives that would at least reduce the dependency on firewood are in sight, it is only a question of time until demand exceeds supply, given currently available resources. The firewood supply problem may not yet be acute in Mali, but the loss of trees has nevertheless led to more soil erosion, which in turn makes it more difficult to carry out afforestation to ensure wood supplies in the future.

Overgrazing

Enlarging Mali's livestock herds in times of good climatic conditions increases the pressure on limited rangeland areas dur-

ing dry spells, with livestock dying as a result. In addition, the loss of nutrient-rich perennial grasses, trees, and bushes that provide shade ruin rangelands. Encroaching erosion causes further damage.

Overuse of marginal soils, erosion, and soil degradation

Rural populations in Mali and in other parts of the Sahel have been forced to extend cultivation into marginal areas to meet the increasing demand for food. But in times of drought, no harvest can be expected in these marginal areas. Their exposed soils are eroded by wind within a short time and will be uncultivable in the long term. Under favorable conditions, recovery might be possible if sufficient fallow time were allowed, but up to 15 fallow years would be required to restore even a minimal level of soil quality. Such lengthy recovery phases are no longer possible today. Once erosion gains a foothold it progresses unless humans intervene.

5 Agriculture

The performance of Mali's agricultural sector, in particular the cereals subsector, largely determines the country's general economic performance and hence the standard of living. Despite the structural weaknesses in rural areas, Mali was able to produce food surpluses as well as export crops up to the 1960s.[9]

Since the 1960s price policies unacceptable to farmers and worsening climatic conditions have brought agricultural development to a virtual standstill. Rapid population growth in recent years has further aggravated Mali's food-supply problems. As a result, the country's dependency on food imports grew steadily during the 1970s, and food aid became a permanent necessity.

The country increasingly has to rely on external food sources even though the area of cultivable land has expanded. Food crops were planted increasingly in areas where the land is better suited for other uses, in particular during years with little rain. There is sufficient rainfall to support extensive agriculture on only one-quarter of the country's total area, and just two percent of the land can be used for intensive cultivation.

The following sections discuss the interaction among the factors most crucial to agriculture and hence to food supply in Mali today. These factors include the natural environment in Mali's climatic zones and the potential for land use, the country's previous agricultural policies, and the food consumption pattern.

5.1 Mali's natural environment and its potential for human use

Erratic rainfall is the main limiting factor for agriculture in Mali, as it is in every Sahelian country. All of Mali is subject to very heavy land-use pressure, which threatens its fragile ecosystems. From the southern part of the country toward the north, rainfall steadily decreases and becomes more variable, and aridity increases. Water resources become scarcer and vegetation cover

and soil quality decline, with a corresponding decrease in the potential for human use of natural resources. The Niger River, which traverses the country's climatic zones, is a life-supporting artery that creates favorable conditions for agriculture within its catchment area.

(Because the natural boundaries of Mali's climatic zones are not fixed, figures 6–9 give only an approximation of the zones.)

The desert zone

Rainfall in this zone is extremely variable in both temporal and spatial terms. As the landscape changes to complete desert, rainfall becomes extremely rare. When rain does come it is only during the summer months, but the water hardly permeates the often thoroughly parched soils, resulting in heavy surface runoff and erosion. Fossil groundwater is the only permanently available water resource in Mali's desert zone. (For problems related to use of fossil groundwater, see Part I, Chapter 5.2)

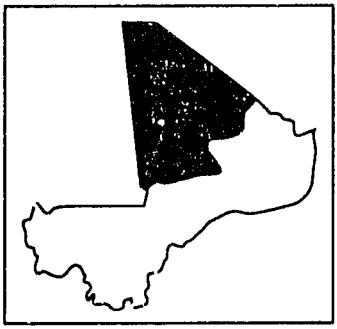
This zone typically consists of raw, sandy soils poorly suited for agricultural use. Soils with a high salt percentage are found in isolated places where low rainfall and high evaporation rates cause salt crusts to form in surface depressions. In the salt pits of Taoudenni, 670 km north of Timbuktu, salt is mined from salt layers in a dry lake bed. This salt is considered to be among the best obtainable and very important in the salt trade.

The desert is largely without any vegetation. Only specially adapted flora, such as succulent plants or annual plants with short life spans, are able to withstand the desert's hostile conditions and to flourish in certain locations. Although rainfall is rare, it is nevertheless sufficient for rapidly growing grasses, which can turn certain areas temporarily into lush green landscapes.

Like the plant life, the animal life in this zone has become specially adapted in order to survive the permanent heat and aridity. It is rare to see animals during the daytime. They emerge from their hideouts only at night, when it is somewhat cooler. Many are able to go without water for long periods. The dorcas gazelle, the dama gazelle, and the addax antelope, which is threat-

Figure 6

Mali's desert zone



ened with extinction, can all live from sparse vegetation and are found in the northernmost part of Mali. Predators such as the jackal, the desert fox, and the wildcat are the natural enemies of antelopes and gazelles. There are also a few species of birds, such as the ostrich and various swallows and sparrows. The most notable reptile is the monitor lizard. With its thick skin and plates that cover its eyes, it does not even shy away from attacks by poisonous snakes. Tortoises that forage at night can also be found in this region.

Land-use potential in desert regions

Despite their hostile conditions, deserts and areas on the fringes of the desert are also human habitats. The desert is the home of the Tuareg, nomads who use camels and keep sheep and goat herds. They are still the "lords" of this region, although they no longer play the lead role they once did in the trans-Saharan caravan trade. The scarcity of natural vegetation in the desert and on its fringes sets narrow limits for nomadic pastoralism and makes intensive grazing is impossible. The distances between the few existing grazing areas are large.

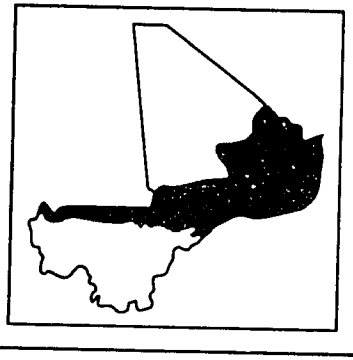
The Sahel zone in Mali

The little rain that falls in Mali's Sahel zone evaporates rapidly, often even before it has reached the ground. The potential water supply is thus very limited. Surface water and subterranean water resources, both of which are renewable and can be used over the long term, exclusively depend on existing water courses. Most groundwater in Sahelian regions is fossil water of ancient origin and therefore non-renewable. The main soil type in the Sahel zone is a sub-arid brown soil, often referred to as steppe soil. It contains little organic matter and few nutrients. Soils like these are highly prone to erosion, especially by wind.

The southern part of Mali's Sahel zone has distinct steppe-like characteristics. In addition to annual grasses, there are also perennial grasses that are reduced to rhizomes (rootstalks) during the dry season and can thus survive underground when water is scarce. Because their root systems stabilize sandy soils, these grasses are very important in maintaining the ecosystem. Succulent plants and various shrubs also flourish in these steppe regions, but larger trees are rare.

Figure 7

Mali's Sahel zone



In the area around Gao 1,750,000 hectares of thornbush landscape have been set aside as a partial wildlife reserve. The well-known *brousse tigrée*, or "striped bush landscape," characterized by belts of vegetation alternating with open areas, can also be found here.

As rainfall decreases toward the north, vegetation becomes spotty and even disappears almost entirely. Cram-Cram grass and other grasses, as well as thorny, thick bushes and isolated spots of low acacia trees, serve as animal fodder. With few exceptions trees shed their leaves in certain seasons and are found only in places where water accumulates periodically.

There are fewer wildlife species in the Sahel zone of Mali than in the savanna areas bordering the zone to the south. Dry spells and hunting have both taken a toll on the region's animal population. Only in a few areas are there animals that one might expect to find here, including dorcas gazelle, dama gazelle, saber or oryx antelope, elephant, and giraffe. These are hunted by spotted hyenas and genets, and, though less often, by lions, cheetahs, or leopards.

Land-use potential in Mali's Sahel zone

While agriculture and pastoralism are often mixed in the southern part of this zone, animal husbandry is the only source of livelihood in the northern part and in areas on the desert fringe. Cultivation, which depends on irrigation and is thus concentrated in the river basins, is highly risky because rainfall is so uncertain. It is possible to cultivate special Sahelian millet varieties in areas where annual rainfall is as low as 250 mm. But if the rains come too late or end too soon, or if dry spells last too long during the growing season, the harvest is likely to be much lower.

Animal husbandry consists largely of raising cattle. Sheep and goat are also kept in the northern part of the zone and camels on the fringes of the desert. Because adverse climatic conditions and sparse vegetation force animal herds to roam over great distances, the way of life in the northern part of the Sahelian zone is mainly nomadic. There are serious fodder shortages from time

to time, because rangeland productivity is low and irregular, especially during dry spells. Herders often enlarge their herds in years when the weather is good, but they do not reduce them during dry years. The inevitable result is heavy overuse of the land in grazing areas.

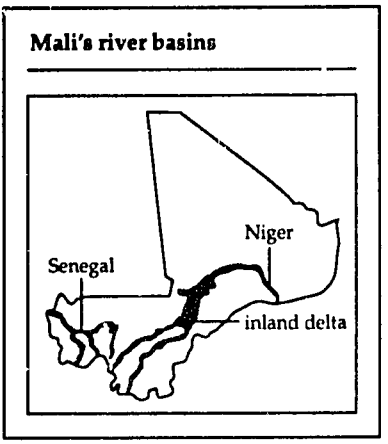
Population pressure emanating from the south is a typical feature of the Sahel zone. More and more land is coming under the plow, and agriculture is continuing to expand to the north, crowding out rangelands in areas that are no longer suitable to be cultivated. Cultivation is thus becoming even riskier, and natural resources are increasingly being overused. Dry years usually bring disastrous consequences, as the early 1970s and 1980s so emphatically illustrated.

River basins

The Niger and Senegal River systems in the western part of Mali not only play an essential role in the country's ecosystem, but they are also a determining factor in terms of land use. We will use the Niger River to illustrate that to some extent the conditions in the basin are atypical for the area where they are found and differ considerably from those in the larger surrounding region.

The Niger River, which flows through Mali from the southwest to the northeast, is the country's principal waterway. The river bends sharply to the south between Timbuktu and Gao and leaves the country in the southeast. The marsh plants and forests that fringe the Niger are the dominant vegetation along the course of the river and its tributaries. They harbor many species of birds and aquatic animals. Because the source of the river is located in the semi-humid Guinea water divide in southwestern Mali, where rainfall is abundant, the Niger carries water throughout the year and transports a considerable volume of this precious resource to drier areas further north. The river is a source for every type of water use and is used to irrigate croplands, especially in the dry savanna and Sahel zones of Mali.

Figure 8



Very special conditions are found in the Niger's inland delta, a 100-km-wide depression with banks that slope very gradually, between San and Timbuktu. When the water is at peak flood stage during the rainy season, it covers about 20,000 sq km, or almost two percent of the country. Soil fertility in this flood plain is maintained at a high level by the addition of natural fertilizers, while the groundwater is simultaneously replenished.

The fantastic fauna in the Niger's inland delta includes more than 130 fish species that are important to the regional economy. Every autumn millions of migratory birds from the north gather in marshlands along the river looking for food and a warmer climate. The delta is also an ideal habitat for hippopotamuses, crocodiles, and fish otters.

Land-use potential in Mali's river basins

The favorable natural conditions of the Niger's inland delta for agriculture make the delta stand out clearly from other areas in the Sahel, which are characterized by their very limited potential. Flood plain agriculture and pastoralism predominate in the

delta, it is the primary rice-growing area, and vegetables and wheat are also cultivated.

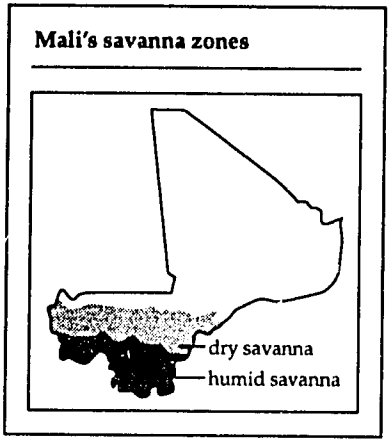
Over the years, dams have been constructed at different levels in the humid savanna (where the source of the Niger River is) to collect annual floods and to store water to irrigate areas further north during the dry season. Although this practice benefits agriculture in the savanna, it may prevent the inland delta further downstream from becoming flooded, which would seriously jeopardize agriculture. Gradual drying out of the delta region would mean the loss of unique plant and animal species as well as the loss of an extremely import agricultural region where rice is the dominant crop.

The savanna zones in southern Mali

The natural potential of Mali's savanna lands falls sharply from the southern border of the country's humid savanna to the northern edge of its dry savanna zone. There are no significant restrictions on water use in the humid savanna zone; most agriculture in this region does not require any irrigation. In the dry savanna zone, on the other hand, water resources must be used economically. The danger of overuse in this zone is already considerable.

Tropical red soils dominate in the southern savanna zones. Clay minerals are very important for soil fertility and hence for agriculture, but leaching causes clay minerals to sink to the lower soil layers. To the west, underdeveloped raw soils predominate. Both these soil types limit agriculture. Patches of sub-arid brown soils are found in the northwestern part of the dry savanna. The area to the west of the Niger inland delta is dominated by vertisols, which contain a great deal of clay and are well mixed as a result of seasonal changes in humidity. These soils are often formed in depressions, where runoff is sluggish, or on broad plains. They are relatively rich in nutrients but very difficult to till. Water erosion affects all the soils in the humid and dry savanna zones to some degree, although the danger of erosion tends to decline toward the north.

Figure 9



Sparse patches of forest and dense layers of grass and herbaceous plants are characteristic of the humid savanna. This zone also houses Mali's only national park, the 350,000-hectare Boucle du Baoulé.

Further north, the forest landscape of the humid savanna gradually gives way to open grassland interspersed with casual tree groves, which is typical of dry savanna. These gnarled trees are seldom higher than 20 meters, and, unlike the trees in the humid savanna, they are deciduous. The Gao tree, the doom palm, the shea tree, the *néré*, the baobab, and the kapok are among the economically valuable trees that make up this parkland savanna. They are cultivated and used, with hardly a patch of good soil left for natural forest growth.

The general appearance of dry savanna is strongly influenced by the amount of seasonal rainfall it receives. During the dry season, the landscape looks brown and parched, but in the rainy season deciduous trees and many grasses transform the savanna landscape into a mosaic in various shades of green. Brush fires, caused on purpose to clear the land for new cultivation, are a threat to savanna vegetation. The Harmattan, the dry, dust-laden wind that blows from the Sahara to the Atlantic coast, often

carries the fires over wide areas, causing great damage to the region's plantlife. Only a few tree species are fire resistant, thanks to their ability to sprout anew from their roots.

Mali's savanna lands are an ideal habitat for many types of animals, including antelopes and gazelles, predators, small animals and birds, as well as aquatic animals along rivers and lakes. Many species of apes can be found, mainly in the dry savanna, while large elephant herds graze in the transition zone between the savanna and the rain forest. But extensive agriculture is depriving many animals of their habitat, leading to an alarming loss of species.

Land-use potential in Mali's savanna zones

While agriculture predominates in the southern part of the savanna zones, agriculture and animal husbandry are equally important, and even complement each other, in the northern part. Both the humid and the dry savanna zones have a wide range of similar food crops, although planting priorities and crop yields vary in each area.

The most important crops are sorghum, millet, maize, rice, groundnuts, and cotton. Legumes, root crops, vegetables, and fruit are less significant in terms of volume and are confined to the humid savanna. In the following paragraphs we will briefly discuss the most important crops.

Sorghum can adapt to a wide range of ecological conditions and is therefore cultivated over a broad area. It is tolerant of both drought and soils with too much moisture, and grows in heavy, clayey soils as well as in light, sandy soils.

Different varieties of *millet* are cultivated from the humid savanna to parts of the Sahel zone with as little as 250 mm of rainfall per year. Millet is not a particularly demanding crop and is relatively drought resistant, although it is quite sensitive to waterlogging and flooding. It grows best in fine-grained sands.

Maize is a more demanding crop. It is especially sensitive to lack of moisture. Crop yields are certain only in areas with at least 800 mm of rainfall per year and not too much rainfall

variability. Maize also requires certain soil conditions. The best conditions for its cultivation can be found in the humid savannas of southeastern Mali. It is relatively resistant to insect pests and birds during maturing, and produces good yields. Over the long term, maize has the potential to replace sorghum and millet to some extent in the humid savanna zone and in the southern part of the dry savanna zone.

Rice, apart from being grown in the inland delta of the Niger, is also cultivated in the periodically flooded plains along rivers in both the humid and dry savanna zones and Mali's Sahel zone. With controlled irrigation, rice can be harvested three times per year. But yields fluctuate greatly because of uncertainties in the hydrologic cycle.

Groundnuts, Mali's main export crop after cotton, requires very specific ecological conditions. Sowing and harvesting times and a steady water supply during the growing season (which depends on rainfall) are the most important factors affecting yields. Rainfall during maturing or too little water prior to grain filling result in lower yields. Groundnuts also require particular soil conditions: successful cultivation requires light, sandy soils free of waterlogging and with a high nutrient content. Continual groundnut cultivation without crop rotation rapidly exhausts the soil. The southernmost regions of the humid savanna and the northern part of the dry savanna are unsuitable for groundnut cultivation.

Cotton can be grown in the entire savanna area of Mali, depending on local conditions. It especially flourishes on well-drained and well-aerated soils that can store water after rainfall.

Natural conditions in Mali's savanna lands will support the cultivation of a wide range of important crops. But specific climatic conditions, climatic variability, and low soil fertility make this region extremely susceptible to any type of overuse. Sustained yields are possible only with land use practices that are suitable for this fragile ecosystem; any type of intensified use is a threat to sustainable development.

5.2 Agricultural policy and its effect on food production

After it became independent in 1960, Mali pursued a radical socialist path of development. The Mobido Keita government (1960–68) nationalized businesses and agricultural operations and established producer cooperatives and state trading organizations, including the Office Malien des Produits Agricoles (OPAM). This office was granted a monopoly on the grain trade.[10] OPAM sold grain through consumer cooperatives, mainly to government employees, and supplied it directly to public institutions such as the army and hospitals. For some time, even roadblocks were used to prevent private shipments of grain. But even in its best days OPAM handled only 20–40 percent of all the grain marketed in Mali.[11] Since only about 15 percent of the total production was ever marketed, the portion of the total handled by OPAM never exceeded three to six percent.[12]

OPAM sold grain at "official" prices. The government fixed official consumer and producer prices for cereals, as governments have done and continue to do in many other developing countries. Three objectives were stated as political justifications for price fixing: increasing rural incomes, providing cheap cereals (chiefly millet and sorghum) to urban areas, and financing state investment in non-agricultural sectors. In reality only the last two objectives were actually pursued.

Official producer prices remained low in order to placate the country's urban population, while income derived from rural areas was used mainly to finance urban projects. Rural incomes remained low as a result. When farmers were reluctant to sell enough grain to the state, OPAM resorted to a policy of forced deliveries.[13]

After the Keita government had been overthrown in the 1968 coup, some of its more radical economic policies were abandoned and OPAM's official monopoly was temporarily abolished. During the drought of the early 1970s, Mali was forced to import large amounts of grain. OPAM had to pay market prices for the commercial imports that did not constitute food aid, but

was obliged to sell it at the low official consumer prices. This caused an enormous budget deficit.

In an attempt to stimulate cereal production following the drought, the government raised official producer prices without proportionally raising consumer prices. The ensuing cumulative budget deficit reached CFAF 20 billion by 1976–77, equivalent to three times OPAM's annual grain sales.[14] Pressure from international aid organizations and the most important donor nations played a considerable role in Mali adopting political reforms in 1981. The reforms were aimed at restructuring the cereals market, and the goal was to eliminate price controls and the state monopoly on rice, millet, and sorghum, with the hope of stimulating domestic production.

In Mali, as in most developing countries, cereal prices are a two-edged sword: on the one hand, low food prices are important in reducing costs for low-income consumers, mainly in the cities. They are also important in the development of crafts and industry and in maintaining internal political stability. On the other hand, because the official prices that farmers receive often do not cover their production costs, low prices are disastrous for producers of food crops. If farmers need an incentive to produce beyond what they need to meet their own food requirements, it will be necessary to raise producer prices. But since prices that provide an incentive to farmers may be too high for poor urban residents, state subsidies or programs to compensate low-income consumer groups are required. This course was not followed by the then Mali government. In an attempt to solve the conflict of interest between farmers and politically influential urban groups, the government allowed OPAM to become the provider of a favored clientele.[15]

The food-price conflict was not confined to rural producers and urban consumers. In Mali's southern rainfed zones, where most surpluses are produced, only 53 percent of farm households are end sellers of grain, while 43 percent are end buyers. The reason for this is that farmers abandon production for home consumption and switch to the more lucrative export crops (e.g. cotton). They can obtain higher prices for these crops and meet their own food requirements by buying grain on the market. In

the northern part of Mali, where rainfall is low, many rural households must also obtain food from the market because they are unable to produce enough for themselves.[16]

It is mainly the better-endowed farmers who have the capacity to increase their grain production in response to higher prices. But these farmers generally tend to invest their resources in relatively stable and profitable crops such as cotton. The vast majority of the small farmers have no access to production-increasing inputs (such as fertilizer, modern seed varieties, plant protection substances), which means they are unable to respond to the incentive of higher prices. Above all, they first would have to have access to the necessary inputs, and they would have to have the prospect of a reliable yield in order to pay back their investments in equipment. At present, most small farmers are simply too poor to make such investments.

Mali's government will have to give priority to solving agricultural problems, and it has to address the question of what the role of the state can and should be in stabilizing the country's cereal market. This role determines not only the motivation and basic economic well-being of farmers who produce for the market but also the food supply for the entire population.

In view of the precarious food supply situation for the poorest of Mali's people, one can only hope that greater priority will be given to help ensure the survival of this rapidly growing and increasingly poorer section. This must take precedence over the past practice of catering for a privileged minority.

5.3 The importance of seed varieties in food production

Throughout the world, but especially in the Sahelian countries, cereals are the most efficient solution for food shortages that have been caused by population growth. Cereals can produce the greatest amount of food with near-balanced nutritional value. Agricultural research has made great progress in increasing and stabilizing cereal production, especially rice.[17] Research has led to production increases not only in extensive cultivation on good soils but also in more intensive cultivation on marginal soils. In

spite of this important development for the Sahel, most attention is paid to rice, wheat, and maize, although these crops alone cannot meet the region's growing food requirements. They are neither the most nutritious grains, nor do they produce the greatest yields given the conditions they require in terms of climate, irrigation, soil quality, and tillage. This situation is all the more regrettable since crops indigenous to the Sahel—above all millet and sorghum—are potentially the best sources for increasing local agricultural production.

Self-sufficiency in food production is not guaranteed in Mali even though approximately 1.5 million hectares of land (about 75 percent of the total area under cultivation) is devoted to millet and sorghum. High population growth rates, stagnation in agricultural production, and low incomes among the rural population are the major obstacles to food security. Average yields vary considerably, ranging from 300 to 1,000 kg per hectare, depending on the region and the amount of rainfall.

The food supply problem affects mainly those living in Mali's arid regions, and they are already the country's poorest. A socioeconomic study in the Cinzana region in 1989 found food shortages in 32 percent of the households, with less than 200 kg of grain per capita per year available.[18] Food insecurity has predictable consequences: increased migration from rural areas and a growing dependency on external aid.

Rapid population growth rates, a shrinkage in the total area of land under cultivation, and environmental degradation pose immense developmental challenges. There is a need for millet and sorghum varieties that can produce higher, more stable yields. It is worth taking a closer look at these two crops since they hold so much promise for the future of the Sahel.

5.4 Millet

Millet is a small-seeded cereal of the grass family *Gramineae*, used as food for human beings or as animal fodder. In the past, sorghum and maize were also included in this category, but in the course of their development they were accorded a separate status.

In many parts of the world production statistics for millet and sorghum are still reported together under "millet."[19] In 1990, total global millet production reached almost 30 million tons, according to the Food and Agriculture Organization of the United Nations (FAO).[20]

History and geographic distribution

Millet is one of the oldest, if not the oldest, of all cultivated groups of crops. Every cultivated variety stems directly or indirectly from wild relatives. Archeobotanists have found traces of millet cultivation in central China that date back as far as the Neolithic Age (6000 BC),[21] whereas rice cultivation began only around 3400 BC. Millets were planted in Chinese provinces near the Yellow River in porous, loamy loess soils in areas with between 250 and 500 mm annual rainfall. The main species cultivated were *Panicum* (proso or common millet) and *Setaria* (foxtail or Italian millet). Typical cultivation tools were hoes and sticks. These early millet species were not confined to the Far East. There is evidence they were known in Mexico (between 4000 and 3500 BC) and in the European Neolithic lake cultures.

The wild millet variety *Setaria viridis* is considered to be the ancestor of the foxtail millet. Unlike cultivated varieties it has brittle spikes. Common millet is descended from the wild variety *Panicum miliaceum*, which has survived for thousands of years and can still be found today as a weed in cultivated millet fields. It loses its seeds prior to maturity. Improved varieties have sometimes developed naturally from wild plants, but they have often been the result of human intervention through careful selection and cultivation.

Selection is probably the oldest plant improvement technique. In its simplest form, it consists of sowing the best seeds of the plants with the best agronomic characteristics in a field with some genetic diversification. Introducing a variety from a different growing area is usually the first phase in improvement, although varieties that flourish well in one region can only seldom be introduced directly into another region because they are usu-

ally not suited to the new environmental conditions. They must first be made "adaptable" through further selection and breeding. This step in the evolutionary process, known as domestication, involves alterations in the genome. This is what makes domesticated plants different from their respective wild relatives.

With the arrival of the plow, the millets were gradually limited to traditional hoe culture areas. Today they continue to play an important role in food production in these areas. The total worldwide area under millet cultivation in 1990 was approximately 38 million hectares, of which 34 million in developing countries—12.4 million in Africa and 20.6 million in Asia, with total production of 8.9 and 16.6 million tons respectively.[22]

Although the average millet yield is low (0.74 tons per hectare in 1993)[23], millet is an important crop because it is so highly adaptable. Throughout the world, many millet varieties have adapted to thoroughly different and even highly unfavorable ecological conditions. The physiological qualities of millet, such as adaptation capacity, short growing periods, and relatively high salinity and drought tolerance, make millet the most suitable cereal type in extreme soil and climatic conditions. No other cereal performs equally well on marginal soils.

Millet, in whatever variety it occurs, has thus become the dominant cereal in the Sahel: in Chad it accounts for 88 percent, in Senegal 81 percent, and in Mali and Niger for 77 percent of total cereal production.[24] Another major advantage of millet is that it is affected by relatively few insect pests and plant diseases. Moreover, virtually no other crop responds so favorably to the slightest improvements in growing conditions (such as irrigation and tillage).

Pearl millet

Pearl millet (*Pennisetum glaucum*) is by far the most important millet species. First domesticated around 2000 BC in the Sahel, it reached India around 1000 BC, where a second major area of genetic diversity developed.[25] Of all the millets, pearl millet is probably the least sensitive to aridity, heat, marginal soils, and

semi-arid growing conditions. Since it is possible to harvest crops even in times of very little rainfall, pearl millet can be grown even on the northernmost fringes of the Sahel. Varieties that mature rapidly flourish on sandy soils with only 180 mm of annual rainfall, although more rainfall will lead to higher yields. Given a sufficient water supply, pearl millet responds especially well on very fertile soils. Because of its great adaptability, pearl millet can be grown in a greater variety of ecosystems than any other cereal except sorghum.

Pearl millet has a high nutritional value: 100 gr of seed contains 356 calories, 125 mg of magnesium, 269–290 mg of phosphorous, and 14.3–42.0 mg of iron. It also contains vitamin B1 (0.30 mg of thiamine) and vitamin B2 (0.16 mg of riboflavin). All millets have a protein content similar to or higher than that of other cereals.[26] Unfortunately, many nutrients are lost during processing. Up to 44 per cent of the proteins, 84 percent of the lipids, 87 percent of the minerals, and over 90 percent of the vitamins can be lost during soaking and bleaching.[27]

5.5 Sorghum

Sorghum was probably first cultivated in 3000 BC in Ethiopia, from where it spread to the east, the west, and the south.[28] According to House, sorghum was mentioned in ancient Indian writings as early as the first century AD, and Pliny reported that it was introduced into Italy from India between 60–70 AD.[29] Sorghum was first cultivated in the New World in the middle of the 19th century; in 1990 the Americas accounted for more than 40 percent of the total world production of 58.2 million tons.[30]

In 1993, 42 million hectares were under sorghum worldwide, of which 18.9 million hectares in Africa and 15.8 million hectares in Asia. This makes sorghum one of the world's most important cereals: after rice and wheat, millet and sorghum rank third in cereals consumption in Asia and second after maize and rice in Africa. Although it accounted for only five percent of total world cereal production in the mid-1980s, sorghum was the fifth

most important cereal crop in the world after wheat, maize, rice, and barley.

There are many varieties of this highly adaptable crop. Along with millet, it is the main calory and protein source for approximately 350 million people in the semi-arid tropics.[31] Rich in carbohydrates, sorghum is relatively low in protein.

Depending on how it is processed, sorghum can be used to make bread (in India, Africa, and Central America), porridge (East and West Africa and India), couscous (West Africa and the Sahel), and alcoholic and non-alcoholic beverages (wine in China and Korea, beer in Africa, and other beverages in Latin America and parts of Africa). White-grained sorghum is normally used for food preparation, while the colored-grain variety is used to make beer.

Sorghum yields vary greatly in the different parts of the world. In the USA, farmers using modern seed varieties, good fertilizer, plant protection measures, and adequate irrigation can obtain yields of up to four tons per hectare. The average yield per hectare for all developing countries is barely one ton. Yields in Sahelian countries are significantly lower than those in the rest of the developing world. Yields in 1993 in Burkina Faso averaged 0.94 t/ha, in Mali 0.93 t/ha, in Senegal 0.77 t/ha, in Chad 0.60 t/ha, and in Niger 0.15 t/ha.[32] This great variation is due not only to the traditional seed varieties used, but also to the fact that almost everywhere in the Sahel sorghum is planted on marginal soils.

5.6 Traditional millet and sorghum processing methods

Traditional methods of processing millet and sorghum demand long hours of hard physical labor, performed daily exclusively by women and girls. Using flails (for sorghum) and pestles (for millet), the women first thresh the grains from the spikes. The threshed grain is put into a wooden bowl and then poured, against the wind, into another vessel. In the process, the wind blows away the light chaff. This procedure is repeated until the grain is free of dust and chaff.

The grain is decorticated with a wooden pestle and mortar—a time-consuming and tiresome task. Then the grain is

washed and sieved. If no sieve is available, the grain is swung on a mat. Two women need an hour and a half just to decorticate and winnow 2.5 kg of grain.[33] The women use 20–49 kilojoules of energy per kilogram of processed grain.[34]

Next, the grain has to be washed and then sun-dried. When the grain is drying, women have the "time" to attend to some of their other tasks, such as tidying up the house and the farmstead, minding the children, obtaining water and firewood for cooking, collecting herbs and leaves, and helping their husbands in the fields.

Then the millet grain is dry enough to be milled into flour. To achieve the desired degree of fineness, the grain is ground once again with pestle and mortar or between two large grinding stones. This part of the procedure takes between two and two and a half hours, depending on the size, shape, and hardness of the grain,[35] and requires an energy expenditure of 34–36 kilojoules per kilogram of processed grain.[36] After some more sieving the flour (and the woman who has made it) is finished.

Since her family is expecting a meal, however, a woman's next task is the cooking. The meal prepared, the male family members are being served first and then the children. It will still be several hours before she has a chance to recover from all this hard work. Only in rare cases can a woman compensate her energy expenditures.

The three most important traditional millet and sorghum dishes in the Malian diet are *tô*, couscous, and *bouillie*. *Tô* is a thick, glutinous porridge, the preparation of which involves several steps.[37] It is dipped into a sauce and eaten by hand. Depending on the household budget, the sauce may be made from baobab leaves and herbs grown in the garden, or it may be served with fish or meat.

Couscous is made by steaming small clumps of flour. It is prepared in different ways and served with different ingredients, such as vegetables, depending on the region.[38]

Bouillie, a millet porridge that can be thick or thin, is used mainly to feed children, but it is also a bland diet for the sick and the elderly. Served with milk and sugar it is a very popular breakfast or desert.

5.7 Millet and sorghum: supply and demand

Supply

As with all cereals, the millet and sorghum supply is a function of the size of the area under cultivation, the use of agricultural implements and inputs, the intensity of tillage and cultivation techniques, and agroecological conditions (such as soil fertility, rainfall, insect pests, and plant diseases). Producer prices are another very important factor in determining supply.

Over the years, millet production in Mali has been erratic. The average annual production of 461,000 tons in 1979–81 rose to 890,000 in 1991, but sank to 691,000 tons in 1993. Sorghum production reached 694,000 tons in 1993, which is double the annual average in the late 1970s (341,000 tons in 1979–81).[59] Current projections do not foresee any spectacular improvements in either total production or productivity in the coming years.

Since the 1973 drought, food imports have made up a substantial part of Mali's cereals consumption. Rice and wheat account for about 70 percent of the grain imports. We have already noted above that this great dependence on imports is due to a combination of erratic rainfall, traditional cultivation methods, continuing environmental degradation, unattractive producer prices, high population growth rates, and neglect of rural development. Fundamental improvement will be possible only if structural change affects several crucial factors in the supply situation.

Demand

The demand for food crops such as millet and sorghum depends to a great extent on a country's dietary habits and disposable income. The current population growth far exceeds current production capacity.

In Mali cereals supply about 70 percent of the total caloric intake in the diet. Millet, maize, and sorghum account for 85 percent of the caloric intake from cereals, while rice supplies the

rest.[40] Other foodstuffs play an almost negligible role in contributing to nutrition.

Rural households meet their food requirements mainly by producing for home consumption (subsistence production). Since few people in rural areas earn wages, which are usually very low and irregular, there is little market demand. As a result, only about 15 percent of the total cereals production is marketed.[41]

But the rural population is continually plagued by temporary food shortages, caused by irregular rainfall and frequent plant pests (such as grasshoppers invasions) and diseases that can ruin entire harvests. In addition, there is a lack of storage and transport facilities that would help compensate for emergency situations.

The majority of the people living in heavily and densely populated urban areas have to rely on the market. But since an average urban household in Mali spends between 35 and 42 percent of its total expenditures on cereals, cereal prices have a great impact on the disposable income of the urban population.[42] This clearly illustrates the political sensitivity of price increases.

Urban areas can be divided very broadly into high-, medium-, and low-level incomes. Although the upper and middle classes are a minority compared with the great mass of poor people, their dietary habits greatly influence Mali's economy. Their demand for imported foods strains the country's foreign exchange position and has a negative impact on domestic production levels because of the multiplier effect.

Imported rice, which usually does not cost much more than local cereals even though it comes from Asia, is the preferred food staple in the cities. Obviously, this has very negative effects on the motivation of indigenous cereal producers, including rice farmers.

Although it is frequently said that rice is luxury food for the wealthy, this cannot be substantiated. But even though rice generally costs (slightly) more than millet or sorghum and has a relatively lower caloric value, it is becoming increasingly popular. One reason is that millet is marketed as a whole grain while rice is generally put on the market as a decorticated grain, which makes the preparation of rice relatively easy and quick; practically no labor is required. Since an increasing number of women in

cities are employed outside the home, less preparation time to prepare meals is an important factor in the choice of food. Rice meals are also cheaper because less fuel is needed for the preparation.[43] With charcoal, firewood, and especially butane gas and kerosene being expensive in the cities, rice has become an attractive alternative.

Feeding an average family on millet or sorghum meals requires considerably more grain than does a rice meal because rice gains much more in volume in cooking. While this may be convenient in terms of food preparation, it is nutritionally disadvantageous, because the increase in volume is not matched by an increase in caloric and protein content.

For the consumer, the slightly higher price for imported rice, compared with locally produced millet, may well offset the added fuel and milling costs and other steps in the preparation of millet.[44]

5.8 Limiting factors in millet and sorghum cultivation

The term limiting factors is understood here to include all negative impacts (economic, technical, ecological, and other) on millet and sorghum cultivation that decrease yield and quality.

Socioeconomic limiting factors

The amount of millet or sorghum yielded per hectare depends first of all on the quality of the seed used and secondly on the effective use of appropriate agricultural inputs, such as fertilizer, plant protection chemicals, and tools. Whether or not these inputs are used in sufficient measure depends in turn on how profitable it is to use them in a certain agroecological environment and on, for example, the structure of the market, producer prices, and access to credit.

The conditions for increasing millet and sorghum yields in Mali have not been favorable up to now. The climate is highly variable, which means the risk of poor harvests is high. Farmers

also use very little fertilizer, because fertilizer prices are too high compared with the resulting increase in yields. Most millet and sorghum farmers are simply too poor to have anything left to invest after taxes and the expenses of supporting their family. The higher returns on export crops such as cotton and groundnuts make investments in modern agricultural tools profitable only for these crops.[45]

Finance institutions rarely grant credits to small farmers for purchasing agricultural inputs, nor are they likely to share the risk of a poor harvest with farmers. Even farmers who manage to obtain credits have trouble repaying when rainfall is below expectations or when unexpected insect pests ruin harvests. They must then resort to their assets and are forced to sell an ox, a cart, or other personal belongings.[46]

Since millet and sorghum prices are fixed by the government, farmers find these crops commercially unattractive. They have always regarded millet and sorghum as subsistence crops and only in special cases as market crops. Consequently, farmers sell these crops only in small amounts and usually only when emergency situations require extra income. After meeting the food requirements of the family, Malian farmers rather invest in more profitable crops such as cotton and groundnuts.

Another problem is the large seasonal fluctuations in millet and sorghum prices. Good yields result in a seasonal glut on the market. Poor storage facilities and a pressing need to immediately earn an income depresses prices and producer incomes in the short term. Farmers who do not produce enough millet and sorghum to feed themselves until the next harvest are hurt in two ways: They are forced to sell at the lowest prices after harvesting, and then have to buy additional grain at considerably higher prices until the next harvest. This situation results in mass poverty and also erodes whatever little investment capacity farmers may have.

But farmers who produce surpluses and who can store their grain are able to market it at more lucrative times, for example when prices are peaking in between two harvests.[47] Investments by the government or farmers' cooperatives in (decentralized) storage facilities could contribute substantially to stabilizing incomes among small millet and sorghum producers.

Small farmers in Mali want to minimize their risks. Farmers choose seed varieties according to palatability, adaptability, and tolerance qualities (although the quality of the existing millet and sorghum seed varieties is generally poor). Because they do not aim to maximize yields (in the case of millet and sorghum), farmers rarely use high-yield potential as a criterion in selecting new seed varieties. When farmers do need to increase their yields for any reason, they often extend the area of cultivated land by expanding into marginal soils, rather than by resorting to intensive cultivation.

Ecological limiting factors

Apart from economic and institutional problems, ecological conditions in the Sahel also hinder agricultural production in Mali:[48]

- There is not enough rainfall. Rainfall deficits are most acute at the beginning and the end of the rainy season. Aridity at the end of the rainfall cycle has the greatest impact on production.
- There is great variability in both the occurrence and the duration of rainfall.
- The spatial distribution of rainfall is uneven during the rainy season.
- Dry spells cannot be forecast. Mali has suffered a number of serious droughts in this century: 1910–16, 1944–48, 1968–73, and 1979–84. Moderate droughts can occur as often as twice within a two- to five-year period. It is therefore important to consider aridity as a feature of the ecosystem, both in Mali and the entire Sahel zone.
- Soils are low in organic matter.
- There is a real danger of soil erosion by water and wind.
- Degraded soils regenerate only very slowly.

Biological limiting factors[49]

- *Insect pests.* Caterpillars and blister beetles, the most widespread insect pests in the Sahel, have forced out millet cultivation in some regions. Mali is also periodically plagued by grasshoppers that can completely ruin an entire harvest within a very short time.
- *Plant diseases.* Fungal diseases attack millet and sorghum crops more frequently than any other plant disease. Downy mildew is the most serious one in Mali, followed by smut and ergot, which occur only sporadically.
- *Parasitic wild plants.* Parasitic weeds can cause up to 60–70 percent of all damage done to millet. These weeds compete with crops for space, light, and water, and also feed on the sap of cultivated plants. Semi-parasites draw water and sap from their hosts, while full parasites also sap starch from their hosts.[50] The semi-parasitic weed *Striga* poses the greatest threat to millet and sorghum. (*Striga* is Latin for a kind of night bird (or vampire in Oriental legends) that is said to feed on the blood of children left unattended at night.) This parasite feeds on host plants by deriving their sap through a direct connection to their roots. *Striga* has been known since the 18th century. Up to 1988, 40 species had been identified, three of which pose particular dangers to crops.[51]

  Striga hermenthica is the most virulent species in Mali. Each plant produces between 40,000 and 100,000 tiny seeds, which are disseminated by wind, humans, and livestock. These seeds can lie dormant in the soil for up to 20 years. *Striga* shows remarkable genetic diversity, a quality that enables it to adapt rapidly to different locations and various host plants. Aridity intensifies the effects of *Striga*, because cultivated plants die more quickly when they lose their sap under arid conditions.[52]
- *Birds.* Birds are fond of millet and sorghum and can cause grave damage to crops. Farmer can either scare birds away, or use "bird-resistant" cereal varieties with strong and long

bristles and husks, and dark husks and seeds. Birds find these varieties less attractive.

- *Low yields with local seed varieties.* Traditional local seed varieties in Mali are adapted to specific agricultural conditions and suit the preferences of local consumers. They have strong root systems that allow them to absorb minerals efficiently from low-fertility soils. They are also very tolerant of the prevailing rainfall conditions in a given location. Their greatest disadvantages are low yields and a poor ability to react to intensifying production measures.[53]

6 Quality Seed for the Sahel

New millet and sorghum varieties in Mali: research, breeding, and production

Mali's alarmingly low agricultural production is due not only to poor ecological conditions, inappropriate agricultural and price policies, and lack of technology. It is due also to unfavorable global economic conditions, including international commodity prices, interest levels, and exchange rate fluctuations. Mali's export revenues are constantly being eroded by increasing import prices, which depresses its financial position. No matter how good a country's development policy may be, without sufficient capital its national development efforts will not come off the ground.

Consistent and sustained action at the national level is essential, however. The main reasons for this are that:

- decisions by political leaders in developing countries can have a direct and important impact on national development; and
- local institutions can help solve local problems through suitable projects and programs. They know how to use local resources best or can supplement these resources with the help of international development cooperation.

If such action is not taken, future catastrophes, such as more famines in the Sahel, will be inevitable.

Mali's development policy, and that of almost all Sahelian countries, needs a general reorientation. Development efforts should focus first and foremost on appropriate rural development and the problems of small farmers. Because Mali and other countries in the Sahel have a very youthful population structure (more than 45 percent of the population is below age 15), a high population growth rate can be expected over the next 10–15 years.[54] Annual crop yields will have to increase by at least four percent

just to keep up with current and future population growth, not to mention sustainable self-sufficiency.

A general reorientation will require political and technological reforms in the agricultural sector. Also, in the long term, it is imperative that the high population growth rate be reduced, and this can be done only by a significant decrease in the birthrate. Unless measures are taken in these areas, there is a danger that any progress made in other areas will have no noticeable effect.[55]

Appropriate technological progress in the agricultural sector will be indispensable. It is becoming increasingly difficult to expand the area of land under cultivation, which makes finding new ways of increasing yields per hectare, and ensuring that these increased yields can be maintained, all the more essential. These priorities underscore the need for more and better local seed research and subsequent breeding efforts, in particular in the case of millet. Breeding techniques that increase and stabilize crop yields are particularly advantageous for developing countries.

In the first place, improvements through seed research and breeding can be incorporated into existing agricultural practices without politically and economically sensitive reforms. The introduction of new, drought-resistant millet varieties may make it possible to grow crops in arid zones where traditional varieties cannot be grown. This would clearly be a breakthrough for the people of the Sahel, even if extension services for farmers, price policies, or other economic and social conditions were not changed (even though change may be necessary).

Breeding is also cost effective; no other investment is as profitable. Perhaps even more important, breeding measures are well accepted by rural populations because farmers usually have some understanding of breeding processes anyway.

One way of achieving greater yield stability and reducing annual fluctuations in yields is cultivating new seed varieties that are resistant to or tolerant of poor soil quality, low rainfall, and biological stress (diseases or pests).

6.1 Resistance and tolerance in relation to ecological factors[56]

In an agroeconomic sense, drought resistance refers to a plant's ability to produce an economically satisfactory yield even if water conditions are poor. Although millet and sorghum are not very demanding crops, lack of water can have a negative impact on yields. Even drought-resistant plants produce higher yields with an adequate water supply.

Breeding techniques to increase drought resistance take advantage of the various mechanisms plants have developed for surviving dry spells:

- Some plants, such as barley and most millet varieties, simply evade drought by virtue of their short growing period. They mature before the next dry spell.
- Other varieties avoid excessive loss of water by using moisture economically. Their vertical leaves play a role in this process, and they may develop deep root systems (as sorghum does).
- A third mechanism is drought tolerance. Plants that tolerate drought develop a number of smaller cells and have stronger cell walls. This enables them to retain water better and to survive when their water content drops. Among cultivated plants, only sorghum belongs to this category.

Usually these physiological mechanisms are combined to develop plant varieties that need very little water or that are good at storing water. Because rainfall is low and unpredictable in the Sahel the breeding of drought-resistant plants is extremely important.

6.2 Resistance and tolerance in relation to biological factors[57]

Biological factors that constitute a considerable hazard to crop yields include plant diseases, animal pests, and weeds. Their effects are completely different from ecological limiting factors. Yield losses caused by downy mildew and *Striga* have caused the

production of millet and sorghum in Mali to stagnate. To reduce the impact of biological factors in an economic manner, plant protection measures are employed. As irrigation, improved tillage, fertilization, and improved seeds increase yields, plant protection requirements increase proportionally.

Aside from cultivation of plant protection techniques (field hygiene, seed selection, improved tillage, and observance of the optimal agricultural calendar as well as observance of growing periods and harvest times), the breeding of disease-resistant plants has also proven to be an effective measure against viruses, bacteria, and fungi.[58] Integrated plant protection is often not possible if plants are not sufficiently disease resistant.

In breeding, yield stability usually takes precedence over high yield potential. Cultivated plants with good resistance qualities are economic for the farmer, do not require any special knowledge, and can be immediately used without any harmful environmental effects.

But developing resistance through breeding is not a short-term process. Using traditional research methods, it can take up to 15 years to develop resistant varieties. Gene technology is expected to produce more rapid results.[59]

The conventional technique for combating *Striga* is hoeing and weeding as soon as the shoots appear aboveground. But since *Striga* has parasitized its host one to two months before it can be detected, irreversible damage has often already occurred. Hoeing and weeding can prevent the weed only from advancing any further. Herbicides can control weeds more effectively, but they can be used only if the host plant is resistant to the herbicide or if the herbicide has a selective effect, which means that it kills the weed, not the crop.[60] Currently, however, there is no "selective" herbicide against *Striga*.

Another option for controlling *Striga* is rotating the crop with crops that are not parasitized by *Striga*. Applying this natural protection method in practice is difficult, because *Striga* attacks many different types of plants. Also, a farmer chooses as his main crop the one that is most profitable or most important to him, and he is reluctant to grow other crops. Lastly, since *Striga* seeds can

lie dormant in the soil for years and thus attack their host at any time, they can make crop rotation futile.

Another method of combating the parasite is to plant catch crops or non-specific hosts. Non-specific hosts induce germination of *Striga* seeds without allowing the weed to attack their roots. Catch crops become severely affected by the parasite. They are sown densely and then plowed under just before the parasite shoots appear. However, this method means that the farmer will have no full harvest.[61]

Using fertilizer to enrich the soil is another option since *Striga* thrives in nutrient-poor soils (which is why *Striga* is not normally found in developed countries). Because farmers cannot afford the relatively high fertilizer prices, this method is unfeasible in Sahelian countries.

In general, it appears that crops that are resistant to or tolerant of ecological and biological limiting factors constitute the most efficient solution for farmers in Sahelian countries. The indigenous crops millet and sorghum have the greatest yield potential in semi-arid areas once the tolerance and resistance of their seed has been improved. Greater research efforts should therefore be devoted to further developing and adapting these two crops.

Until the mid-1970s, few research and breeding programs in the world focused on millet, in spite of the fact that it plays a prominent role in the diet of large segments of the population in the semi-arid and arid tropics. This need for research was one of the arguments for founding the Station de Recherche Agricole (Agricultural Research Station) in Cinzana, Mali.

6.3 The Station de Recherche Agricole in Cinzana, Mali

The Cinzana Agricultural Research Station was established in 1979 as a joint project of the Government of Mali, the United States Agency for International Development (USAID), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT—one of the centers in the Consultative Group on International Agricultural Research (CGIAR), see also p.100), and the

Swiss CIBA-GEIGY Foundation for Cooperation with Developing Countries. Cinzana is a small village in the main millet-growing area of the country, about 35 kilometers east of Ségou between the Niger and Bani rivers.

The Cinzana Research Station was officially opened on July 15, 1983. The opening was the first achievement of what later was to become (quite literally) a fruitful collaboration among the four partners. The Government of Mali offered 280 hectares of land, with five different soil types on it. The government and ICRISAT jointly designed the station and its research facilities, while USAID and the CIBA-GEIGY Foundation shared the investment costs.

The station became an integral part of Mali's national research program, which is controlled by the government. A Malian director, Dr. Oumar Niangado, was put in charge of the station.

The station's main compound contains research laboratories, offices, storage areas, workshops, and living quarters. Three generators generate all the electricity the station needs, and it is therefore independent of the often unreliable electricity supply from the grid. Water is pumped up from a source seven km away and piped to the station. Of the station's 280 hectares, about 80 are currently being used, leaving ample space for expansion of the research and breeding work.

Until 1989, when USAID and ICRISAT ended their support, as contractually agreed[62], the foreign partners helped to finance recurrent expenses and provided technological, scientific, and management support. USAID and the CIBA-GEIGY Foundation jointly covered all other operating costs until 1989 (such as equipment, instruments, motor vehicles, fertilizer, seed, and fuel). Since, the CIBA-GEIGY Foundation has solely funded operating costs.[63] From the start, the Government of Mali has covered the personnel costs of the (permanently appointed) Malian civil service staff at the station.

Since the Government of Mali had long cited domestic food production as inadequate, the Cinzana Agricultural Research Station was given the task to promote this. Priority was given to achieving sustainable increases in pearl millet yields. Research had to be aimed at enabling small farmers, who are the main pearl

millet producers throughout the Sahel, to have access to improved seed varieties and better cultivation techniques without having to obtain any additional, expensive inputs. All evaluations of the station indicate that this aim has been achieved.

The station's first task was to find varieties whose genetic qualities suited the environmental conditions best. To that end, researchers selected the most productive varieties among the traditional species. An essential requirement for breeding is plant material with a broad variability. This makes it possible to select and reproduce genotypes with the best characteristics. To avoid losing valuable genes from traditional varieties of a certain plant, its various species, primitive forms, and wild relatives must be collected, analyzed, and stored systematically. The station has set up a seed bank with all local and some wild millet varieties, about 1,200 in all. It has also experimented with millet varieties from India and North America, but the results showed that imported millet varieties were unsuitable for both cultivation and seed breeding in the Sahel. Among the local varieties, certain lines were identified as ideal for breeding.

Early-maturing varieties from southern Mali with a growing period of only 90 days were selected and planted in the north of the country. Even in this part of the country, where rainfall is low, satisfactory harvests were obtained with these varieties. In the southern part of the millet-growing region, small farmers plant parts of their fields with the early-maturing variety. By harvesting their own early millet and use it to feed their families, farmers no longer have to pay high prices for millet hoarded by dealers.

Good yields were obtained with *Toroniou de Níngali*, a millet variety from the Dogon Plateau. It underwent reselection and was then crossed with varieties selected in Cinzana. This new variety increased yields by up to 13 percent or 60 kg per hectare to a total of 514 kg/ha. Moreover, *Toroniou de Níngali*'s growing period is one week shorter and more drought and pest resistant. *Toroniou de Níngali* produces these results under conditions typical of subsistence agriculture in Mali and other Sahelian countries.

Although 60 kg of millet per hectare may seem a modest increase, it is enough to feed one child for one year. The Cinzana

station produces basic *Toroniou* seed to pave the way for more extensive seed production. The station set up demonstration fields and organized excursions for farmers from all over the region to illustrate the qualities of this reselected millet variety.

New cultivation techniques such as intercropping with alternate rows of millet and cowpea have also been highly successful. This very simple improvement offers numerous advantages. The total millet and cowpea yields with this type of intercropping rose by about 10 percent to 722 kg/ha. Thanks to its nodule bacteria, cowpea can fix nitrogen from the atmosphere and use it to enrich the soil. Sowing and cultivation is also easier with this method.

Cowpea's resistance to *Striga* slows down the expansion of this weed. Since cowpea and millet have different growing periods, fragile soils are covered longer and therefore better protected against erosion by rain and wind.

One very interesting result of the efforts to improve agriculture through *local* intercropping methods was that yields increased when planting was carried out in a systematic manner. Repeated experiments confirmed that, compared with the traditional, arbitrary intercropping methods or with millet as a monoculture, yields were measurably higher when alternate rows of millet and cowpea were systematically and carefully planted. Intercropping of millet and cowpea also reduces the risk of harvest failure when rainfall is irregular, because the available moisture is more fully exploited.

Research at the Cinzana station also deals with the selection and breeding of millet varieties that resist downy mildew, and it attempts to breed hairy grain husks, which are less prone to be lost to birds. In addition, it uses farmyard manure and composted millet stalks to improve fertilization. After several years of study, for example, it was found that the addition of straw increased manure substance by 42 percent without reducing the nitrogen content of the manure. Field experiments have shown that this simple fertilization technique can raise yields by 30–35 percent.

A review of the Cinzana Agricultural Research Station by external consultants in January 1992 concluded, as previous reviews had,[64] that the station is doing outstanding work. The

station serves as a model research institution for Mali and other Sahelian countries.[65] (See also the Appendix.)

Cinzana's successful research and breeding work shows that it is not necessary to wait for major agricultural breakthroughs to solve highly complex problems such as basic food security in the Sahel. In time, many small or modest successes add up to substantial improvements.

6.4 Nutrition research in Mali

The Cinzana station collaborates with Mali's food-research institute Laboratoire de Technologie Céréalière de l'Institut d'Economie Rurale (Cereal Technology Lab of the Agricultural Economics Institute) in Bamako to complement the station's research. The lab concentrates on researching genetic material in the course of selection, the nutritional qualities of cereals, and the use of these cereals in daily diets. Additional work is being done to enrich the traditional children's diet with cereals and legumes. New ways of preparing food in the home are also being sought.

Apart from physiological and chemical analyses, "culinary" tests are carried out. Traditional Malian dishes are prepared with new blends of flour, which panels representative of the general public test for taste and general appearance.

Test meals may consist of millet or sorghum, mixed with cowpea or soybeans, to prepare *tô*, couscous, and other dishes. Sweet desserts are made with new combinations of wheat and millet, wheat and sorghum, or wheat and cowpea.

It is hoped that mixtures help to increase the nutrient level in the traditional Malian diet. Traditionally, millet, sorghum, and other cereals are prepared separately. Depending on household income and the availability of other ingredients, these cereals may be mixed with milk, sugar, groundnuts, vegetables, root crops, meat, or fish. These ingredients are more or less crucial; if they are not available, which is usually the case among the poor, meals will not meet the daily human nutritional needs. The diet may be adequate in terms of caloric intake but deficient in necessary nutrients such as proteins, essential fatty acids, vitamins, miner-

als, and trace elements. Such deficits are a chronic problem in Mali and all developing countries.

Children under age five and pregnant and breast-feeding mothers are most at risk from malnutrition. Normally, a woman who eats a normal diet gains 12–13 kg during pregnancy. In countries like Mali, where malnutrition and undernutrition are endemic, pregnant women often gain only three–four kg. This makes women a great deal more susceptible to disease and puts them at a much greater risk of suffering from a miscarriage or giving birth prematurely. Because they weigh so little at birth, premature babies are much more likely to die in infancy. Malnutrition in young children stunts growth and inhibits brain development.

The Laboratoire de Technologie Céréalière de l'Institut d'Economie Rurale attempts to help solve these problems. Research at the lab aims to increase the nutritional value of flour made from cereals by adding flour from legumes, in particular cowpea. Cowpea contains up to 24 percent of protein and is widely cultivated in many regions of Mali. Cowpea and millet flour is mixed in proportions of one-quarter to three-quarters and administered to infants to supplement breast-feeding. This approach is particularly effective because it doubles the lysine content in flour, from 2.5 mg/g to 5 mg/g (lysine is an essential amino acid in a healthy diet). The lab and the Cinzana station teach courses on dietary enrichment at health centers and to women's groups in all areas where millet is the basic food.

6.5 Production and distribution of selected seed varieties in arid zones

The research and breeding of new seed varieties that are adapted to the adverse conditions in the Sahel is an important element in the efforts toward greater food security in the region. But research and breeding are not enough. New seed varieties must be reproduced and made available to the region's small farmers. One of the many projects that the Food and Agriculture Organization of the United Nations (FAO) is carrying out in

collaboration with the United Nations Development Program (UNDP) and the Government of Mali aims to reproduce and distribute improved seed varieties to farmers.

The project focuses on seed varieties that are adapted to the local growing conditions and that guarantee yields of two to four tons per hectare. Modest yields, yes, but under the prevailing Sahelian conditions of marginal soils, little or no fertilization, and little plant protection, they are more realistic than those that can be achieved with high-yield varieties, which produce excellent harvests only under controlled experimental conditions.

The most important requirements for quality seed are a short growing period, disease resistance, and drought tolerance. New varieties should also suit the local consumer's palate, and food preparation should require the same amount and kind of work.

Seed varieties produced at the Cinzana Agricultural Research Station were introduced in villages in every climatic zone in Mali. The next step is to produce and market sufficient quantities of quality seed from varieties that prove successful in each area.

Seed production is a demanding undertaking. In Mali it involves the following steps:

- The Cinzana station first plants "elite" seed on 1.5 ha on its own compound. Staff involved in seed research and production closely collaborate to exchange their experiences with the seed. This seed is called "breeder seed" and is carefully stored for further production.
- The first production (R_1) of seeds is carried out on state farms (on approximately 20 ha per year). Sales of R_1 seed are expected to support cultivation costs once the project ends.
- Village associations have been formed in all Mali's climate zones where the FAO is active, to carry out the second production (R_2). This final phase of seed production results in the planting seed that is to be used by farmers. This is the most labor-intensive phase because it involves the biggest seed increase.

- During planting and after harvesting, the quality of the seed produced (elite, R_1, R_2) is examined by an independent government certification agency. The seed may then be certified as "quality seed" according to international standards. (Even if it does not receive this rating, the seed is good enough to be used as food.)
- Certified R_2 seed is then made available to farmers. Since uncontrolled crossbreeding under natural conditions may result in a drop in quality, millet and maize seed must be renewed every three years (cowpea seed every four years).

The FAO project is integrated in Malian seed-production and certification institutions. It strongly supports these institutions to help to upgrade the quality of the work, depending on the particular phase of the production process.

In 1990, the project, in collaboration with Malian development organizations, supervised seed production in 16 village associations. The associations produced and marketed 250 tons of certified R_2 seed—235 tons of millet, 10 tons of maize, and five tons of cowpea. In 1991, 25,000 ha of millet, 350 ha of maize, and 250 ha of cowpea could be cultivated with quality seed.

Every year, the state agricultural extension network determines the amount of seed that the seed-producing associations need to produce. The associations also sell seed to farmers and provide information about the varieties. Fields where the varieties are grown in demonstration plots serve to support this information task. Seed sales are announced in various local-language radio programs, where association members report on their experience with new varieties.

Most farmers everywhere have a healthy skepticism of new developments. In the Sahel, given the extent of rural poverty, farmers are reluctant to immediately use unfamiliar seed varieties. They do not want to take risks with their harvest, because a failed harvest can have very serious implications for the entire family. A new variety may also be unacceptable because it doesn't agree with the local taste. To change taste, and to convince farmers that the new varieties actually improve yields, takes time. Introducing new seed varieties is therefore a slow, step-by-step process.

The worst thing that can happen to a seed project is to produce seed that cannot be sold. For several reasons, seed prices are not subsidized. It was therefore essential for this project to establish the right price for R_2 seed. On the one hand, the price had to be high enough to provide those producing the seed with an incentive to grow it; on the other, it had to be low enough so that farmers, who are mostly very poor, could afford it. This problem was solved to the satisfaction of all parties by resorting to traditional barter, whereby a farmer who is short of money can repay his seed with grain after the harvest at a 1:2 ratio. (For example, a farmer who needs seven kg of millet seed, which is enough for one hectare, can repay his debt after the harvest (of approximately 514 kg) with 14 kg of millet.)

It is estimated that, by the time the project comes to an end, enough R_2 seed for 195,000 ha will have been produced and sold. The main object of the project, however, is to create a system that will continue to benefit agriculture in Mali by supplying farmers with sufficient amounts of high-quality seed at reasonable prices.

Notes

1 All figures used in this chapter refer to the situation in 1992, except where indicated.
2 World Bank, *World Tables 1994*. Washington, D.C. 1994.
3 Figures in this paragraph from World Bank, *World Tables 1994*. Washington, D.C. 1994.
4 See, for example, Sasson, A., "Effects of climatic variation on production." In Sasson, A., *Feeding tomorrow's world*. Sextant Series No. 3. UNESCO/CTA. Paris. 1990. p.253.
5 World Bank, Op. cit. p.244.
6 Data are taken from FAO, *Agrostat Database 1994*. (on diskette) Rome. 1994.
7 FAO, Ibid.
8 On the general problem of population and the conditions necessary for a drop in birth rates, see Leisinger, K.M., *Hoffnung als Prinzip. Bevölkerungswachstum: Einblicke und Ausblicke*. Birkhäuser Verlag. Basel, Boston, Berlin. 1993.
9 See Lecaillon, J. and Morrisson, Ch., *Economic Policies and Agricultural Performance. The Case of Mali 1960-1983*. OECD. Paris. 1986. p.19.
10 Ibid. pp.19 and 76 f. See also Staatz, J.M., Dioné, J., and Dembélé, N.N., *Cereals Market Liberalization in Mali*. World Development, Vol. 17, No. 5. Pergamon Press. Oxford. 1989. pp.703-718.
11 Humphreys, C.p.*Cereal policy reform in Mali*. Draft Report. World Bank. Washington, D.C. 1986. p.5.
12 See Staatz, J.M. et al. Op. cit. p.704.
13 See also Mondot-Bernard, J., and Labonne, M., *Satisfaction of food requirements in Mali to 2000 A.D.* Development Centre Studies. Development Centre of the OECD. Paris. 1982. p.41.
14 See Staatz, J.M. et al. Op. cit. p.705.
15 Ibid. p.706.
16 Ibid. p.712.
17 See, for example, Leisinger, K.M., *Grüne Revolution: Eine revidierte Beurteilung im Lichte neuer empirischer Erfahrungen*. Aussenwirtschaft, 39. Jhg, H.IV. 1984. pp.357-381, and "Die "Grüne Revolution" in Wandel der Zeit: Technologische Variablen und soziale Konstanten." Published as *Social Strategies Forschungsberichte*. Vol 2, No. 2. Basel. 1987. See also Swaminathan, M.S., *Science and the Conquest of Hunger*. New Delhi. 1983.
18 Diourte, Z., *Etude socio-économique aux environs de la station de recherche agronomique de Cinzana*. IER-DET. Bamako, Mali. 1990.

19 See Rachie, K.O., *The Millets. Importance, Utilization and Outlook* International Crops Research Institute for the Semi-Arid Tropics (IRCISAT), Hyderabad, India. 1975.

20 The exact amount was 29,817,000 t; see FAO, Op. cit. p.83.

21 The primary source of information for this section was Plarré, W., "Entstehung und Verbreitung der Kulturpflanzen." In Rehm, S. (ed.), *Handbuch der Landwirtschaft und Ernährung in den Entwicklungsländern*. Band 3, "Grundlagen des Pflanzenbaues in den Tropen und Subtropen." Eugen Ulmer Verlag. Stuttgart. 1986. p.193 ff.

22 See FAO, Op. cit. p.84.

23 This is the global average according to FAO *Production Yearbook 1993*. The corresponding data for Africa is 0.66 t/ha and for and Asia 0.81 t/ha. The average yield in the industrialized countries was 1.14 t/ha.

24 Rehm, S. "Hirsen." In Rehm, S. (ed.), Op. cit. Band 4, "Spezieller Pflanzenbau in den Tropen und Subtropen." Second edition, completely revised and expanded. Eugen Ulmer Verlag. Stuttgart. 1989. p.79 f.

25 Ibid. p.80 f. See also Hanna, W.W. "Utilization of Wild Relatives of Pearl Millet." In ICRISAT, *International Pearl Millet Workshop Proceedings, 7-11 April 1986*. Patancheru, A.P./India. 1986. p.34.

26 Rachie, K.O., Op. cit. p.48. See also Rooney, L.W., and McDonough, C.M. "Food Quality and Consumer Acceptance of Pearl Millet." In ICRISAT, Op. cit. p.43 ff.

27 See Rachie, K.O., Op. cit. p.29. See also Rooney, L.W., and Mcdonough, C.M., Op cit. p.53.

28 See mainly House, L.R. "Sorghum." In Rehm, S. (ed.), Op cit. Band 4. p.40 ff. See also Sasson, A. "Achievements and potential: International cooperation and prospects. The 'green revolution.'" In Sasson, A., Op. cit. p.488 f.

29 See House, L.R. "Sorghum." Op. cit. p.42.

30 All statistics are taken from FAO, Op. cit. p.85 f.

31 See Sasson, A., Op. cit. p.489 ff.

32 See FAO, Op. cit.

33 See Chinsman, B., "Choice of technique in sorghum and millet milling in Africa." In *Proceedings of the Symposium on the Processing of Sorghum and Millets: Criteria for Quality of Grains and Products for Human Food, 4-5 June 1984*. International Association of Cereal Chemistry. Vienna, Austria. p.83-92.

34 See Haidera, M. and Bengaly, M.A., *L'expérience du laboratoire de Technologie Céréalière dans le Domaine de l'Utilisation des Farines Composées*. Ministère de l'Agriculture/Institut d'Economie Rurale. Bamako, Mali. 1990.

35 See Chinsman, B., Op. cit.
36 See Haidera, M., and Bengaly, M.A., Op. cit.
37 See Rooney, L. W., and McDonough, C.M., Op. cit. p.47. Rooney and McDonough give a very vivid description of the preparation methods for very different traditional meals.
38 Ibid. p.50.
39 See FAO, Op. cit.
40 See Staatz, J.M., Dioné, J., and Dembélé, N.N., Op. cit. p.704.
41 Ibid.
42 See Rogers, B., and Lowdermilk, M. "Price policy and food consumption in urban Mali." In *Food Policy*. December 1991. p.461-473.
43 Ibid.
44 Ibid.
45 See Staatz, J.M., Dioné, J., and Dembélé, N.N., Op. cit. p.713. See also Coulibaly, O.N. "Aspects Socio-économiques de la production du mil et du sorgho au Mali." In ICRISAT, *Mil et sorgho au Mali. Communications présentées au Séminaire sur le mil et le sorgho au Mali. Bamako, Mali, 4-8 October 1988.* pp.29-37.
46 Among other sources, see Coulibaly, O.N., Op. cit. See also Niangado, O., and Traoré, K.A. "Amélioration variétale du mil, Pennisetum glaucum (L.) R. Br., au Mali Bilan de dix années de recherche. Orientations futures." In ICRISAT, *Mil et sorgho au Mali.* Op. cit. pp.129-156.
47 See Dioné, J., and Staatz, J.M., *Market liberalization and food security in Mali. Agricultural Economics Staff Paper No. 87-73.* Michigan State University, Department of Agricultural Economics. East Lansing, Michigan. 1987.
48 Among other sources, see ICRISAT, *International Pearl Millet Workshop Proceedings.* Op. cit. p.19 f.
49 Ibid. p.143 f. See also Niangado, O., and Traoré, K.A., Op. cit. p.133.
50 See Alkämper, J. "Unkrautbekämpfung in den Tropen und Subtropen." In Rehm, S. (ed.), Op cit. Band 3. p.459 ff.
51 See Sasson, A. Op. cit. p.490 f.
52 Ibid.
53 See Niangado, O., and Traoré, K.A., Op. cit. p.135.
54 Forecasts of this nature assume either no change or a slight decline in the mortality rate; they do not consider the possibility of catastrophes such as a dramatic spread of AIDS.
55 For a thorough discussion of the problems of population growth in poor countries, see Leisinger, K.M., *Hoffnung als Prinzip.* Op. cit.
56 Rehm, S. "Oekophysiologie der tropischen und subtropischen Nutzpflanzen." In Rehm, S. (ed.), Op. cit. Band 3. p.106 f.

57 Kranz, J., and Zoebelein, G. "Pflanzenschutz in den Tropen und Subtropen." In Rehm, S. (ed.), Op. cit. Band 3. p.377 ff.

58 Ibid. p.388 ff.

59 On gene technology and its uses and risks in developing countries, see Leisinger, K.M., *Gentechnik für die Dritte Welt?* Birkhäuser Verlag. Basel, Boston, Berlin. 1991.

60 Alkämper, J., Op. cit. p.451 ff.; especially p.459 ff.

61 Ibid.

62 The amount pledged by contract (1990-1995) was Sfr 500,000 annually. This sum does not include peripheral costs (scientific activities, administration, laboratory management, etc.) and other personnel costs.

63 USAID limited its own role because the CIBA-GEIGY Foundation constituted a strong partner for continued financing. USAID's departure from Cinzana allowed it to take up other, more regionally focused activities of equal urgency.

64 Examples include evaluations done by ISNAR (International Service for National Agricultural Research) in 1989 and ICRISAT/USAID, in 1990.

65 See Yudelman, M., *An Evaluation of the Research Station at Cinzana, Mali.* Washington, D.C. and Basel, 1992. (Ciba-Geigy Foundation for Cooperation with Developing Countries). A brief report on some of the lessons learned from this project appears in Niangado, O., Scheuring, J.F., and Yudelman, M. *A Private-sector Foundation's Support to Developing-country Agricultural Research,* Briefing Paper 20, ISNAR, The Hague, The Netherlands, February 1995. This Paper is reprinted here in the Appendix, p.193.

III Conclusion

Conclusion

Environmental degradation, inappropriate agricultural policy, the hardships endured by women, and lack of suitable seed are examples of problems which in themselves constitute formidable obstacles to improving life and agriculture in the Sahel. But the survival of the people of the Sahel is threatened in particular by the synergetic interaction of these disparate problems.

Any approach that holds the promise of solving these problems can be compared better to painstakingly piecing together a difficult puzzle than to cutting the Gordian knot. Appropriate development policies at the national level are needed, which must focus first and foremost on the three biggest problems in the Sahel: agricultural stagnation, an unacceptably high population growth rate, and degradation of the natural resource base.[1]

Financial and technical support from international development cooperation organizations may facilitate and complement local development policies and perhaps even speed up success in some cases. But such support cannot substitute local efforts.

Since isolated measures are seldom effective, a coordinated package of measures adapted to specific local conditions will be required. These measures will have to be agreed upon in conjunction with local populations, be acceptable to them, and then be jointly implemented with them. History has shown that projects and programs that are forced upon a population are doomed to fail, in the Sahel and everywhere.

Much more than a few years of adequate rainfall, reforestation programs, or new seed varieties is required to enable the people of the Sahel to live a viable existence rather than merely survive. There are many similarities in the political, social, economic, and technological obstacles to development in the Sahelian countries (Chad, Niger, Mali, Mauritania, Burkina Faso, Senegal, and the Gambia). These obstacles will have to be re-

moved, first to guarantee survival and then to improve the quality of life in the long term. This will mean promoting rural development to allow productive use of rural resources in ways that are socially acceptable and protect the environment. The productive potential of rainfed agriculture in the Sahel is limited by natural conditions. Full and ecologically acceptable utilization of this potential will require major changes in the political and economic spheres in most Sahelian countries.

Suitable priorities must be set to stimulate rural inhabitants of the Sahel to play a role in economic and social development. Specifically, their potential to act must be promoted and supported, and they must be allowed and encouraged to act more independently, with greater responsibility, and with more self-determination. The people of the Sahel themselves must (again) assume the lead role in solving their problems, and external support must be designed in a way that encourages this. In the long term, such external support should no longer be necessary.

This, incidentally, is one of the central conclusions of a critical review of international development efforts in the Sahel, carried out in 1984.[2] The review led both donor and recipient countries to revise their development strategies.

At the minimum, development policy must include the following:

- Political decision making that "combines the free market principle with the social equilibrium principle."[3] This means creating an environment that encourages economic development by, for example, promoting private initiatives. It also means abolishing fixed prices and introducing sociopolitical policies that enable the poor to satisfy their basic needs.
- Construction and development of infrastructure, such as roads, transport and storage facilities, electricity, health care and education institutions, drinking water supplies, and irrigation systems.
- Measures to protect the environment and preserve non-renewable resources.
- Promotion of small businesses and local crafts.

- Promotion of social changes, to give women equal social rights, include them as equal partners in all development activities, and grant them equal participation in the economic fruits of their labor. In short: the enforcement of human rights for women.

Rural development projects and programs should be as (local) labor intensive as possible. The purchasing power that is thus created in rural areas can promote the development of markets and product diversification, and thus bring about other related developments.

Rural development strategies for sustainable agricultural development deal with a number of issues that, though equally important, may vary from region to region:

- Mobilize the rural population by creating and strengthening institutions that stimulate the use of available problem-solving potential and initiatives.
- Support socially acceptable use of human capacities and more effective and efficient use of natural resources, while preserving the resource base.
- Develop rural extension services that focus on the specific needs of small farmers, both male and female. Farmers must also have a dependable supply of all the inputs they need (tools, seed varieties, fertilizer, and plant protection chemicals).
- Improve credit and marketing systems (and assured access to these systems for both sexes). Development of cooperatives should be given much more emphasis, since their aim of "common action to create real assets" is an especially important component in solving the problems of the people of the Sahel.[4]
- Intensify agricultural research and development aimed at finding and putting into practice new ways, means, and methods of increasing environmentally sound production of food and export crops.

Traditional and modern natural resource management methods must be more closely linked in the future to promote

agricultural development. Examples include less use of slash-and-burn techniques, allowing reforestation in erosion-prone areas, development of ecologically acceptable forms of cultivation such as agroforestry, and improved rangeland management.[5] In the interest of development, it is very important that any measures taken support men and women engaged in small-scale farming, since they constitute the majority of the population in the Sahel.

The economic, social, and ecological outlook in the Sahel appears bleak at the moment, but there are signs of hope if one knows how to recognize them.

The Republic of Niger, for example, has proven that considerable success is possible in the Sahel if there are appropriate agricultural policies and if measures are purposefully aimed at promoting rural development. Socially, climatically, and ecologically, Niger is a typical Sahelian country. Nevertheless, in 1984—a crisis year in the Sahel—Niger produced enough agricultural surpluses to export food to its neighbors without endangering its own domestic food demand. Price policy for food crops was the main factor that enabled farmers to increase production, while specific investments in rural infrastructure also helped. Surpluses were used to build food reserves, which ensured domestic supply during the 1984 crisis.

Chad, on the other hand, is an example of how a lack of national policy affects agriculture. Rural development was completely neglected in Chad due to continued political unrest, and armed conflicts caused further problems in the food supply.

What is the significance of seed and seed-related research in this context? The availability of seed that is adapted to specific environmental conditions and that suits local needs is certainly not sufficient to solve all the problems. But it is one necessary piece in the broad mosaic of rural development and one specific tool that can help to achieve self-sufficient production. Without suitable seed, no further developments are possible, even with the best agricultural policy. Seed research and development (and agricultural research in general) is therefore of central importance. This is especially true when research and development is carried out locally, (as at the Cinzana Agricultural Research Sta-

tion or other similar research stations), when it focuses on local problems and needs, and when results are not patented. Only then can new seed be sold at affordable prices to the men and women engaged in small-scale farming.

Food imports and external food aid must eventually be replaced by self-sufficiency, and subsistence agriculture must evolve to provide small farmers with a means of living. To achieve this, it will be necessary for farmers to have access to seed that produces an adequate harvest on the stubborn soils of the Sahel.

If a technological step forward of this kind were accompanied by suitable political, economic, and social reforms, and, if necessary, supported by external development aid, we would hopefully no longer have to speak of "survival in the Sahel," but of "life in the Sahel."

Time is running out for instituting developmental and technological change in Sahelian countries. The current social, economic, and ecological problems are so huge, and the degradation processes so evident, that we must take heed of the "ethics of time," as the Club of Rome admonished:

"In conclusion, the speed of evolution and of current mutations leads us to consider that the time factor has an ethical value in itself. Every minute lost, every decision delayed means more deaths from starvation and malnutrition, means the evolution to irreversibility of phenomena in the environment. No one will ever know for sure the human and financial cost of lost time."[6]

Notes

1 See also McNamara, R., *Africa's Development Crisis: Agricultural Stagnation, Population Explosion, and Environmental Degradation. Global Coalition for Africa.* Washington, D.C. 1991.

2 See OECD, CILSS, and Club du Sahel, *Proposals for a Revised Strategy for Drought Control and Development in the Sahel.* OECD. Paris. 1984.

3 Alfred Müller-Armack described his concept of the "social market economy" in *Wirtschaftsordnung und Wirtschaftspolitik. Studien und Konzepte zur sozialen Marktwirtschaft und zur europäischen Integration.* Freiburg i. Br. 1966. p.243.

4 See Trappe, P., "Zur Entwicklungsfunktion des Genossenschaftswesens unter Berücksichtigung vorgegebener Sozialstrukturen." In Trappe, P.*Entwicklungssoziologie.* Published as Social Strategies Vol. 12. Basel 1984. (Edited, with an introduction, by H.W. Debrunner). pp.205-224. See also "Wege zu einer afrikanischen Genossenschaft?" Ibid. p.417-430; and Trappe, P.*Die Entwicklungsfunktion des Genossenschaftswesens am Beispiel ostafrikanischer Stämme.* Luchterhand, Neuwied und Berlin. 1966.

5 See Manshard, W., *Entwicklungsprobleme in den Agrarräumen des tropischen Afrika.* Wissenschaftliche Buchgesellschaft. Darmstadt. 1988. p.15 f. On agroforestry, see Von Maydell, H.-J., "Agroforstwirtschaft in den Tropen und Subtropen." In Rehm, S. (ed.), Op. cit. Band 3. p.169 ff.

6 King, Alexander, and Schneider, Bertrand, *The First Global Revolution. A Report by the Council of the Club of Rome.* Pantheon Books. New York. 1991.

Appendix

LESSONS LEARNED:

A PRIVATE-SECTOR FOUNDATION'S SUPPORT TO DEVELOPING-COUNTRY AGRICULTURAL RESEARCH

By ISNAR in collaboration with O. Niangado, J.F. Scheuring, and M. Yudelman

Since its inauguration in July 1983, the agricultural research station in Cinzana, Mali has established a relevant mandate, a well-focused program, and a functional organization within a complex national agricultural research system (NARS). The station is well staffed (some 10 researchers and 20 technicians), competently managed, under sound leadership, and has generated new and useful technologies. More importantly for present purposes, Cinzana is an example of a unique approach to donor and technical assistance.

In its founding years the station benefited from joint donations and technical support from the United States Agency for International Development (USAID), the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), and the Swiss CIBA-GEIGY Foundation for Cooperation with Developing Countries. Most recently, the CIBA-GEIGY Foundation has been the main provider of external financial support and very limited technical assistance. In this, the Foundation, a philanthropic arm of the Swiss multinational chemical corporation, is demonstrating how the private sector can support research oriented towards small-scale, poor farmers in sub-Saharan Africa.

The Cinzana research station is often cited as a model of international cooperation. Reviews of the station have revealed a series of key factors in its success. Taken together, these factors provide some lessons for successful external support to developing-country agricultural research institutes. This Briefing Paper presents some of these lessons. A first lesson for donors is that research requires a long-term financial commit-

This appendix was previously published as *ISNAR Briefing Paper 20*, February 1995, The Hague: ISNAR. ISSN 1021-2310.

ment of at least 15–20 years and a willingness to fund non-salary recurrent expenditures. A future important lesson is that a research station's relevance may be jeopardized if its program does not continually adapt to the needs of its target farming community. Private-sector involvement can facilitate both sustainable support and adaptability. A final section of the Briefing Paper highlights the evolving role of the CIBA-GEIGY Foundation in supporting the Cinzana station. NARS leaders as well as decision makers in industry will benefit from these lessons and may find opportunities to apply them under their own conditions.

A New Venture in Agricultural Research

The agricultural research station in Cinzana, Mali began operations in 1983. The Malian government, USAID, ICRISAT, and the CIBA-GEIGY Foundation for Cooperation with Developing Countries were the four partners involved in planning, building, and operating this new public-sector venture in agricultural research. In constructing the station, USAID and CIBA-GEIGY bore the bulk of the capital costs, while ICRISAT and the Government of Mali sited and designed the facilities.

The station was designed to be an integral part of the Malian agricultural research system, operated by the Malian government and staffed by Malian personnel. The non-Malian partners provided advice, technical assistance, and funding. ICRISAT provided scientific advice. Funds were provided by USAID and the CIBA-GEIGY Foundation, which funded equipment, vehicles, and recurrent operating expenses.

The four partners continued their relationship until 1990, when USAID and ICRISAT terminated their support. This was not because of dissatisfaction with the project. Rather, they wanted to focus their resources on projects with regional, as opposed to largely national implications. Indeed, in their final project evaluation both USAID and ICRISAT urged CIBA-GEIGY to continue funding the Cinzana research station, and to provide additional funds to fill the gap arising from their withdrawal. After its own

internal review of the situation, the CIBA-GEIGY Foundation undertook to fill this gap and, provided the center's performance warranted it, to provide sustained support over the foreseeable future.

CIBA-GEIGY now has been involved in the project for some 15 years. While other donors are involved in supporting particular research projects at the station, CIBA-GEIGY has been the major external partner since 1990. Thus far, the Foundation has contributed about five million Swiss francs. Under the current five-year contract (1990–95), it provides the station 500,000 Swiss francs yearly. Essentially, the Malian government pays staff salaries, and CIBA-GEIGY provides between 80 and 90 percent of the station's operating funds.

Establishment and Management of the Project

Focus. In 1979, the CIBA-GEIGY Foundation set out to initiate an agricultural research project to benefit small-scale African farmers. The head of agricultural research in Mali suggested that the Foundation help to establish an agricultural research station in the Malian Soudano-Sahel. From the beginning the objective was clear: to establish a national agricultural research station for the improvement of millet-based agriculture. With that mandate, in 1980 Mali's Ministry of Foreign Affairs gave the CIBA-GEIGY Foundation official status as a nonprofit technical assistance agency.

Repeatable Lesson: A common, well-focused objective should be defined early, with clarity on the part of both the donor and the host country.

Continuity. During the construction of the station, CIBA-GEIGY seconded, on a periodic basis, a civil engineer from its Basel headquarters to help oversee the work and to follow through on purchases. Upon completion of construction, the Foundation created four part-time support positions: project manager, research support scientist, station management support, and electric engineer. These are filled by staff sent from CIBA headquarters. Each

of these positions requires an average of 10 days per year spread over one or two trips.

The CIBA-GEIGY support persons are associated on a long-term basis with the Cinzana project. Accordingly, they are very familiar with their Malian counterparts and with specific needs at Cinzana. Built-in, long-term expertise ensures pertinent, timely support from the Foundation to the project. However, because external support is periodic, Cinzana's Malian staff are able to demonstrate leadership and initiative. Because there are no expatriate staff salaries to bear, the Foundation's financial support is focused almost entirely on Malian on-station expenses.

Repeatable Lesson: Long-term technical assistance is essential for research projects. The benefit of long-term assistance can be sustained by using persons seconded for short periods but with lengthy, well-defined associations with the project. This formula ensures pertinent expertise and continuity at a minimum cost for expatriate support. At the same time, it fosters the full-time responsibility of national staff. Local staff enjoy their own successes; they also make their own decisions and mistakes, but with sustained support as it is needed.

Working partnerships. At the beginning of the project, a board of directors was established to oversee the development of the research station. Membership is the head of agricultural research in Mali, the Cinzana station director, the station accountant, a CIBA-GEIGY Foundation representative, and a representative from another donor to the station. Until 1990 an ICRISAT staff member served on the board. With the termination of ICRISAT's involvement and an increase in Dutch project funding, a Dutch representative has served on the board since 1992.

The role of the board is to oversee finances, maintenance, and the research orientation of the station. The board meets formally once each year, but interacts informally more regularly. Over the years the board has served to foster clear communications, to provide a forum to settle differences of opinion, and to give moral and political support to the station's director.

Repeatable Lesson: The creation and operation of a board of directors composed of both Malian leadership and representatives of key donors and support groups enhances transparency in finances and management and provides a legitimate forum for input from all key partners regarding the repartitioning of the budget. This also ensures that donors have a forum in which to insist on result-driven research.

Physical Establishment of the Station

Site choice. The station site was decided after several months of reconnaissance studies in the Segou area of Mali. The chosen site contains all of the major Malian agricultural soil types on one contiguous piece of land. It also offers the possibility of growing good crops of both millet and sorghum, and is situated in close proximity to a mix of traditional farming systems and ethnic groups in nearby villages. Accessibility by road also was an important consideration.

Repeatable lesson: In hindsight, the most important element of siting the station was its reasonable proximity (5 km) to a paved national road with a fairly good laterite access road. Of all the Malian agricultural research stations, the Cinzana station has the best accessibility.

Water. Only after commencing building construction was it discovered that the groundwater recharge was insufficient to permit an adequate water supply from wells dug on the station. Rather than "making do" with a feeble water supply, or having water hauled onto the station in cisterns, project leaders decided to find an adequate water supply in the proximity and to pipe water onto the station. A Swiss hydraulic engineering team was brought in and discovered a very adequate underground tributary at 12-meter depth, seven kilometers from the station. Buried pipe was installed and turn-out valves were provided intermittently along the pipeline to allow for irrigated isolated fields. An electric pump was installed at the well site and an elevated water storage tank was erected on the station.

Systematic annual water analyses over the past 13 years have confirmed pure, uncontaminated water. The availability of pure water has translated into an unusually low incidence of intestinal parasites and other ailments among station personnel and their families residing on the station. Adequate water has been a major factor in attracting good Malian researchers to reside on the station. Pure water has contributed to excellent hygiene standards on the station. Also, the regular, reliable water supply has enabled dry-season breeding nurseries to be established and for seed production to be increased every winter. Irrigation capacity has enabled the Cinzana breeding programs to produce two generations per year. It additionally has given the station the flexibility to quickly multiply seed of promising experimental varieties of millet, sorghum, cowpeas, and groundnuts.

Repeatable lesson: The initial expense and bother of finding a good water supply is well worth the money and the effort expended.

Housing. In addition to low-cost but adequate housing for principal and support staff, a conference hall and guesthouse were constructed on the Cinzana station. Initially four rooms, the guesthouse has now been expanded to eight rooms. The availability of this clean, comfortable accommodation attracts visiting researchers and encourages them to spend adequate time at the station to complete all necessary tasks. The guesthouse has been used by dozens of students, both Malian and expatriate, doing thesis work. The conference hall is used not only for Cinzana staff meetings, but also has been the site of numerous regional meetings and training sessions.

Repeatable lesson: The construction and operation of a clean, comfortable guesthouse attracts a regular flow of visiting scientists to the station. This enhances the value of the research done and provides a stimulating environment for the regular exchange of ideas between visitors and staff.

Stable and corral. Animal traction is the standard tillage and cultivation power used on many traditional farms in the Segou area. Research leaders therefore integrated animal and mechanical cultivation techniques for experimentation on the Cinzana

station. Animal traction training techniques were imported from India whereby one person leads the animals using voice commands. Adequate infrastructure was provided for the animals, which average about 50 head. In addition to meeting its own traction needs, Cinzana regularly supplies traction animals to other Malian research stations. The animals provide routine farm power, serve as tools for improving farming techniques, serve at training sessions, and provide manure for compost experiments.

Repeatable lesson: The importance of animal traction may justify the provision of adequate infrastructure for farm labor animals.

Fencing. In the Malian countryside, freely roaming animals frequently damage farmers' fields by eating plants or walking through fields. The precision of agronomic research cannot tolerate such damage. Cropped fields must be protected and adequate pasture must be ensured for the station's herd. To these ends, a 1.6 meter fence was erected around the station's perimeter. As a public road transects the station, the total fence perimeter is 10 kilometers. The fence mesh is small enough to keep out sheep and goats. Adequate gates are provided for vehicles and pedestrians. The fence is regularly monitored and repaired when necessary. Bushes planted along exposed sections break the wind and prevent damage. Now, 13 years after construction, the fence and gates are still in excellent condition.

Repeatable lesson: The erection and maintenance of adequate fencing provides experiment fields with excellent protection against animal damage and ensures the protection of pasture for station animals. The fence is especially important for protecting irrigated crops during the winter, when local farm animals are allowed to roam free.

Baseline studies. A series of baseline studies to describe and quantify water, soils, socioeconomics, crop varieties, and farming methods was carried out at the beginning of Cinzana station research. Results of these studies can be compared with similar surveys to be conducted in future years. In 1980, in conjunction with the Swiss hydrologic exploration, Cinzana researchers surveyed the wells in the villages surrounding the station. Estimates

were made of high- and low-water levels during the year. In 1982–83 an extensive soil survey was conducted on all five of the Cinzana soil types. A station soils map was carefully drawn with references made to permanent markers. That map since has been used to record an accurate crop and fertility history. In addition to the map, a soil "library" was collected, with samples from 300 sites at three depths each. The soil survey also provided contour information that was used to construct permanent earthen terraces. Maintained with grass since 1983, these have held firmly against erosion. Finally, in 1984 a Malian team of economists conducted an extensive socioeconomic survey designed in collaboration with ICRISAT. The survey aimed to produce data comparable with other such studies in the Sahel. Villages within a 50 kilometer radius of the Cinzana station were characterized for ethnic and household organization, field sizes, cropping patterns, and income sources and levels. In 1989 a follow-up survey was conducted in many of the same villages. Using the results of both surveys, adoption rates of some agronomic techniques were readily and accurately detected. A third follow-up study was carried out in 1994.

Following the 1984 socioeconomic survey, millet varieties were collected and millet varietal preference was surveyed. These samples and information have been the basis for the establishment of varietal and agronomic reference checks in experiments carried out on the Cinzana station.

Repeatable lesson: The information collected at the onset of station operations provides a reference point for detecting changes in water levels, soil fertility, and village socioeconomic conditions, as well as for calculating technology adoption rates.

Establishment of an On-Farm Research Program

The need for an on-farm testing program became evident in 1985, when researchers discovered that some station-developed intercropping techniques were complete failures in farmers' fields. The major reason was the significant difference in soil fertility between

farm and station fields On-station millet yields were regularly two to three tons, while they rarely surpassed one ton on farmers' fields. In addition, researchers discovered that under farm conditions many millet and sorghum varieties developed on-station gave significantly lower yields than local varieties.

Before 1985, the Cinzana station conducted research only on the station itself. On-farm research was designed, planned, and executed by a group of agronomists based in Mali's capital, Bamako. After considerable pressure from the board of directors, a position was created at Cinzana for an agronomist to carry out on-farm trials designed by the Bamako-based group. The Cinzana agronomist gradually was given more autonomy until, from about 1991, on-farm experiments were designed, executed, and reported entirely by Cinzana staff.

By 1993 Cinzana's on-farm research program included three village "antennas," with station personnel living temporarily in village centers during the crop season to follow test plots. The on-farm program now embraces a network of more than 50 on-farm locations supervised both by the station agronomist and by collaborative extension services. The on-farm research program also plants several demonstration fields along major roads and entrances to weekly markets.

The on-farm agronomist also serves as the station's liaison person with regional extension agencies, and regularly participates in extension planning meetings, training activities, and farmer demonstrations. The agronomist also ensures the transfer of accurate information and pure seed once the technologies are confirmed through on-farm tests. Technology transfer from the Cinzana station has been facilitated by regional extension agencies that have received ample funding through the World Bank and the International Agricultural Development Fund (IFAD). Locally adapted, proven technologies suggested by the Cinzana station have been backed by the funding agencies, which are determined to make visible, measurable, on-farm impact.

Repeatable lesson: The creation, support, and operation of an on-farm testing research program play a determinant role in assessing the relevance of station research as well as in directly contributing to the efforts of local extension agencies. It is essential that the on-farm testing program be planned locally, rather than by a centralized group in another location.

Research Planning and the Technology Pipeline

Until 10 years ago, most Malian food crop research was directed by scientists headquartered at Sotuba in Bamako. Stations such as Cinzana were merely testing sites for Sotuba-designed experiments. With its attractive infrastructure, however, many of Mali's better scientists were enticed to transfer to and reside on the Cinzana research station as early as 1983. Before coming to Cinzana, the station's first director had been responsible not only for millet breeding, but also oversaw the strategic direction of the other food crop breeding programs in Mali. Cinzana soon became the base for all millet research.

Initially, each year's research results were reviewed at an annual national research meeting. At the same meeting the research program for the coming year was approved. The meeting, however, was broad, national in scope, and did not provide a sufficiently detailed overview of the flow of technologies from discovery to adoption by farmers. With the creation of the on-farm research group and the on-farm success of Cinzana's early maturing cowpea varieties, it became obvious that an annually updated technology pipeline was needed. This pipeline would track the flow of technologies through stages, from the definition of research objectives and exploratory testing to extension on farms.

In 1987, a technology pipeline was designed for the Cinzana station based on existing Malian procedures and comparable to the technology flow in a commercial seed company (tables 1 and 2). Cinzana technologies are categorized as varietal, technological, or plant protection. Chronologically, the stages in the pipeline are definition of objectives, station exploratory tests, station pre-

Table 1. Blueprint of the technology pipeline of a private seed company compared with that of the Cinzana reseach station

Private seed company		
Stage of development	**Duration (years)**	**Locations**
Commercial sales	5-15	varies widely
↑		
Product development (large on-farm plots)	2	minimum 12 average 20
↑		
Small plot trials	3	6-14
↑		
Varietal or technological development	3-4	1 station
↑		
Definition of objectives (interdisciplinary encounters)	-	3-4 times per year

Public agricultural research in Mali		
Stage of development	**Duration (years)**	**Locations**
Extension	long term	varies widely
↑		
Pre-extension and multilocational tests	2-3	5-12
↑		
Preliminary and advanced tests	4-6	6-10
↑		
Exploratory testing	1-2	1 station
↑		
Definition of objectives (interdisciplinary encounters)	-	1-4 times per year

Table 2. Stages, objectives, tasks, and measures of progress in the Cinzana research station's technology pipeline

Technology pipeline of the Cinzana research station, Mali				
Stage of development	**Objective**	**Duration (years)**	**Tasks**	**Measure of progress**
Extension	Meet farmers' needs	-	Communication and demonstration	Adoption rates
↑				
Pre-extension	Final confirmation of technology	2-3	Test on-farm quality information packages	Useful feedback
↑				
Multilocational tests	Confirm technology's performance on-farm	2-3	Conduct on-farm trials	Positive results
↑				
Advanced testing	Confirm technology's performance on-station	2-3	Conduct research station trials	Positive results
↑				
Preliminary testing	Evaluate the technology's potential	2-3	Conduct research station trials	Positive results
↑				
Exploratory stage	Identify promising varieties and techniques	1-2	Conduct preliminary observations of innovations	Preliminary success
↑				
Definition of objectives	Provide research focus	-	Organize interdisciplinary encounters	Clear research focus

liminary trials, station advanced trials, on-farm confirmation, on-farm pre-extension trials, and extension.

In addition to clarifying planning and facilitating monitoring, the pipeline overview highlights research and extension successes, and serves as a vehicle for clear communication among research's stakeholders.

In its technology pipeline, Cinzana innovated by establishing an "exploratory testing" stage. Researchers are allowed to test any innovative, preliminary ideas in a single replication for one year—just to check the feasibility of an idea. If preliminary results look promising, then the theme may become a formal, replicated on-station research theme. If not, the theme is thrown out without having spent significant resources. Exploratory testing has been an effective method for identifying new agronomic intercrops such as millet-manioc and millet-yam, both of which have successfully gone on to formal station experimentation.

Repeatable lessons: The definition of an annually updated technology pipeline brings transparency to station research planning and monitoring. It also clearly identifies for extension agencies those themes that will soon reach on-farm application. The flexibility for researchers to do exploratory testing encourages innovation at minimum expense.

Research Results and the Technology Pipeline

The Cinzana research station as an institution has evolved from focusing only on improving millet to addressing a broader range problems facing the Segou area farming communities. Cinzana research results are best outlined in its current technology pipeline (table 3). Key technologies that have reached on-farm adoption are presented in chronological order.

Key technologies at the adoption stage

Early cowpea varieties. Starting in 1984, the station produced cowpea foundation seed that was later grown by Malian state seed production farms. Some of the seed produced at Cinzana escaped informally in the hands of seasonal workers. Within two years there was a strong demand for the new varieties. The two best adapted varieties were selected at Cinzana. They were obtained from the International Institute of Tropical Agriculture (IITA). By 1986, an IFAD-funded project had diffused several tons of seed to farmers in the region along with appropriate insecticides. The socioeconomic survey of 1989 determined a full 45 percent adoption rate of the new cowpea varieties within a 50 kilometer radius of the station.

Cowpea-millet flour blends for weaning foods. Preliminary research done by the food technology group at Sotuba indicated that a 25 percent blend of cowpea flour in weaning and adult food was undetectable by consumers, while doubling the protein and lysine content of the food. With the unexpected success of the new cowpea varieties, there was suddenly an abundance of cowpeas in local households. Cinzana researchers confirmed the Sotuba group's findings in villages and dispensaries around Cinzana. A

Table 3. Detail of the 1993 technology pipeline of the Cinzana research station

Technology pipeline of the Cinzana research station, Mali 1993			
Stage of development	**Varietal**	**Agronomic**	**Pest control**
Extension	Toroniou millet Early cowpea varieties (KN-1 and Gorom-Gorom)	Alternate row millet-cowpea intercrop Composite millet-cowpea flour for weaning food 'One man, one team' animal traction method	Apron-Plus seed treatment Striga control in cowpea by genetic resistance (Gorom-Gorom)
Pre-extension tests (on-farm)	ICRISAT millet ICMV-88-102-04	Rotations within millet-cowpea intercrop Millet-groundnut intercrop	Combined effect of manure application and Apron-Plus seed treatment
Multilocational tests (on-farm)	Early groundnut varieties Sorghum variety	Managed farmyard manure use	-
Advanced testing (on-station)	Millet and sorghum selections Virus-resistant manioc selection	Millet-manioc intercrop Zizyphus living fences	-
Preliminary tests (on-station)	Varietal crossing in millet, sorghum, cowpeas, and groundnuts	-	Selection and recombination of mildew-resistant millet Selection and recombination of leaf-disease-resistant sorghums
Exploratory tests	Introduction of orange-flesh yams in millet-yam intercrop	Millet-yam intercrop Managed farmyard manure in intercrops Effect of timing on manure applications Vitamin analyses of baobab fruit and orange-flesh yams	-

brochure and poster (in both the French and Bambara languages) were created with the assistance of the CIBA-GEIGY Foundation, and the theme was launched for extension in 1989. Since then, radio information spots, demonstrations, and training sessions have been conducted. The Cinzana station leadership on this theme has had a national impact.

Alternate row millet-cowpea intercropping. Following initial failures with more complicated schemes, Cinzana researchers found a simple intercropping of alternating rows of millet and cowpea to be a success. On-farm tests indicate a consistent 10 percent increase in total grain yield per area compared with crops of only millet or only cowpeas. In addition to the yield advantage, the technique offers flexibility in cultivation and harvest, excellent wind-erosion control, and a built-in blueprint for millet-cowpea rotation whereby the farmer simply plants millet on the ridges where cowpeas were grown in the preceding year. This technique was launched for extension in 1991 and was being adopted with great success by the summer of 1993.

Toroniou millet variety. Toroniou is one of 850 local millet varieties screened for various characteristics in 1981–83. Toroniou was found to have remarkable tolerance to stem borer, as well as wide adaptation within Mali. Toroniou originally came from a remote village in the Dogon country. Until recently, it was not known in the Segou region, although it is very well adapted there. Toroniou was reselected and purified by Cinzana personnel, tested on-farm, and has been widely extended by extension agents. On-farm tests indicate average grain yields about 10 percent higher for Toroniou compared with the local varieties.

Mixed technology package. Toroniou was extended in 1993 in a technology package along with the millet-cowpea intercrop, a Striga-resistant cowpea variety (Gorom-Gorom), and the use of an insecticide-fungicide seed treatment called Apron-Plus. This technology package results in yield gains as high as 50 percent compared with local varieties and production techniques, even without additional fertilizers.

Apron-Plus seed treatment. Apron-Plus is a CIBA-Switzerland seed treatment mixture of one fungicide and two insecticides. In the mid 1980s it was successfully introduced in Nigeria to control downy mildew on maize. As downy mildew is a major millet disease in Mali, Apron-Plus was tested on-farm by Cinzana staff beginning in 1988. In four years of on-farm tests, Apron-Plus improved yields an average of 30 percent due not only to mildew control, but also to soil insect control, bird repulsion, and a slight but detectable growth boost to young seedlings. It ensures seedling establishment from a single planting. Uniform emergence and growth translates into uniform seed setting and plump grain formation. These encouraging on-farm results have prompted the CIBA seed treatment unit and plant protection farmer support team to become interested in developing the product commercially in West Africa for millet. After an initial prelaunch of 250 kilograms (sold in 10 g sachets) in 1992, more than 2.5 tons were sold in 1993, and five tons were planned for sale in 1994. In 1993 alone, an estimated 12,500 extra tons of millet were harvested in Mali thanks to the seed treatment. The CIBA-GEIGY Foundation did not intend the Cinzana project to bring commercial benefit. Likewise, Apron-Plus was not developed with millet as a target crop. But Apron-Plus works well on millet, and the Cinzana station effectively measured the benefits. Now Malian millet farmers reap the results.

Key technologies in the pipeline

New millet and sorghum varieties. After more than 10 years of breeding work, new experimental millet and sorghum varieties appear promising enough for on-farm testing. The CIVAREX series of millets are medium height (about 1.5 m while local varieties are 2–3 m) and offer yield potential slightly greater than local varieties. Selections were grown on-farm in 1994. The sorghum varieties are local tall varieties and high-yield short-statured varieties, but with significantly higher yield potential than the locals. In both cases, the research objective is to establish intensive and sustainable intercropping systems.

Rational use of manure and compost. Experiments are now under way to maximize the fertilizer effectiveness of farmyard manure by composting it with straw, and by changing the method of application. Already, on-farm trials indicate that application of only 3–4 tons manure per hectare improves millet yields on the order of 20 percent. In exploratory tests, application placement, amount, and timing are being varied on the millet-cowpea intercrop in order to optimize the fertilizer effect while minimizing the amount of manure applied. The objective is to produce a manure recommendation that can be used to further enhance the millet-cowpea intercrop and crop rotations.

Use of living fences. The agroforestry group at Cinzana discovered a native bush (Zizyphus sp) that establishes well without depressing yields of adjacent millet crops. The berries produced by the bush are used as a household condiment. The use of living fences to protect areas against roaming animals is an idea welcomed by farmers. Traditionally, winter hedges are constructed from cut branches, competing with firewood uses. The first Zizyphus seedlings were distributed to farmers in 1994. Methods are now being developed to enable farmers to grow their own Zizyphus tree nurseries.

Millet-manioc and millet-yam intercropping. Both the millet-manioc and the millet-yam intercrops have proven very promising in on-station experiments. Success with these methods may lead to the widespread introduction of manioc and yam propagation stocks, now lacking in the Segou area. Manioc cuttings were distributed to some farmers in 1994.

Social marketing of natural vitamin sources. Fruit from the Baobab tree contains a very high concentration of vitamin C (2200 ppm), and are found in abundance in the Sahel. While people do use the fruit for drinks and gruels, they are unaware of its vitamin content and health benefits. Similarly, the orange-flesh yams introduced in the millet-yam intercrop contain a high level of vitamin A. Vitamin A deficiency is a chronic health problem in rural Mali, yet the vitamin A benefits from orange-flesh yams is

not widely known. In collaboration with agronomists, foresters, and food technologists from other institutes, Cinzana researchers will promote a social marketing message of these benefits in 1995–96, once the millet-yam intercrop is ready for on-farm testing.

Repeatable lessons: To retain its relevance, a research station must continually update its core program to adapt to the changing needs of its target farming community. An interactive link between station and on-farm research helps to maintain links with farmers, and is determinant in a station's ability to produce appropriate technologies. Finally, the use of a technology pipeline can be vital to maintain the focus of research on well-defined technology packages and time frames.

The Evolving Role of the CIBA-GEIGY Foundation

Initially, the CIBA-GEIGY Foundation established a number of criteria about the type of agricultural project it might support: the project should be in a poor country, it should benefit poor farmers, it should increase food production, and it should be part of a government effort rather than an expatriate enclave. Additionally, the project was to be noncommercial in the sense that it was not intended or expected to develop market opportunities for products made by the CIBA-GEIGY corporation in Switzerland. The decision to support the Cinzana research station met these criteria.

The Foundation's role evolved as circumstances changed. Initially, it was to join USAID in cofinancing the management and operation of the research station. The Foundation also provided some technical assistance, especially with regard to the layout and management of the station's workshops and the maintenance and operation of farm equipment. The technical aspects of the Cinzana research program were assisted by staff from ICRISAT. CIBA-GEIGY also had a representative on the research station's board of directors, which has met infrequently to review station operations. With the withdrawal of USAID and ICRISAT, the Foundation took on a bigger role in the agrotechnical aspects of the station's work.

Over the long run it is likely that CIBA-GEIGY will continue to be called upon to provide more scientific support to the researchers at Cinzana. Many of these scientists are recent graduates who could benefit from the advice and views of the scientific staff of the CIBA-GEIGY corporation itself. Such support could be pivotal in reducing the sense of isolation of researchers and enhancing the quality of research.

About the Authors ...

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Survival in the Sahel revisits the baffling puzzle of the development problems of the Sahel zone of Africa. Using practical examples and sound data, it shows how past development strategies have contributed to the region's deteriorating socioeconomic and environmental conditions. It also shares some of the success stories of the last two decades, recommending new development approaches, and presenting some alternative ways to deal with the present Sahelian situation.

The book is divided into two parts. Part I discusses the Sahel, its geography, history, environment, and socioeconomics. Part II highlights the case of Mali as a typical Sahelian country. Together, these sections raise a number of lessons and implications. First, global solidarity among aid organizations is a prerequisite to solving the problems of the Sahel. Second, new development strategies have a better chance of success if they have a long-term perspective, are based on small-scale actions, use a more integrated approach, take more account of women, and seek the full participation of local people. Third, the contribution of agricultural research to solving the problems of the Sahel, its people, and its natural environment cannot be ignored. Fourth, even organizations that do not have development assistance as their main *raison d'etre* can and should be involved in the development of the Sahel.

Survival in the Sahel addresses readers who have no particular prior knowledge of the subject. Published by ISNAR with the support of the CIBA-GEIGY Foundation for Cooperation with Developing Countries, it is an expanded and updated version of the original German-language work published in 1992.

ISBN 92-9118-020-3