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Primary Land Productivity Assessment

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POTENTIAL OF FORAGE LEGUMES IN LAND-USE INTENSIFICATION TOWARDS SUSTAINABLE CROP-LIVESTOCK PRODUCTION SYSTEMS IN WEST AFRICA

VOLUME 1

PRIMARY LAND PRODUCTIVITY ASSESSMENT

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Poverty, high population pressure on land-use, and the inability of maintaining fertility through traditional farming and land management practices are contributing to land degradation and decline in agricultural productivity in most West African countries. Improved farming practices and land management alternatives that can raise productivity and protect the agricultural resource base are urgently required to meet future food demands.

It was in this context that the potential of forage legumes in crop-livestock systems in West Africa was examined by ILCA. The ability of forage legumes to biologically fix nitrogen and provide livestock feed of good quality are potential benefits offered by adapted legume fallows compared to natural fallows used in traditional systems. These are important considerations in effective management of nutrients and soil fertility through crop-livestock systems.

Previous work in West Africa has considered forage legumes mainly from a viewpoint of their potential contribution to livestock feed improvement; their potential contribution to soil management has not been systematically assessed. This joint ILRI/FAO/IIASA work addresses the potential of both.

This report on "Potential of Forage Legumes in Land-Use Intensification: Towards Sustainable Crop-Livestock Production Systems in West Africa" is composed of two volumes.

Volume 1 deals with the FAO-AEZ methodologies of land productivity assessments and presents results of primary land productivity for a number of forage based land utilization types.

Volume 2 presents the application of the Spatial Optimal Resource Model (SORUM) for the assessment of the implication of improved primary land productivity for crop-livestock systems, and for meeting future (year 2010 and 2025) national and regional food demands.

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CHAPTER 1: INTRODUCTION

1.1 Background

The two decades of poor rainfall in West Africa since the early seventies and the severity of the drought and famine in 1973/74 and again in 1984/85 has highlighted the imbalance between the vulnerable land resources and crop and livestock production activities in the region. The emerging problems of desertification, deforestation, overgrazing and soil erosion has resulted in intensive national and international efforts to understand and tackle the underlying causes of this environmental crises and to plan for sustainable and viable development strategies. Although considerable scientific and technical information has been gathered and numerous commissions and local projects started, there is a general lack of concerted regional programme implementation to tackle the inter-related and inter-disciplinary environmental problems, which if left unchecked could result in irreversible loss of the natural resource base in many countries in West Africa.

The policies and programmes to tackle the environmental problems, requiring substantial financial resources and long term commitment have to be implemented in a situation of stagnating economies, poverty and a degrading resource base, particularly in view of:

- Declining agricultural production and food self-sufficiency for rapidly increasing populations
- Disruption of social systems; e.g. traditional pastoral-agrarian relationships;
- Apparent changes in long-term climate and variable rainfall;
- Lack of government finance for social and health interventions and increasing depth burden;
- Rural-Urban migration and the inability of urban economies to cope;
- Declining foreign exchange earnings - mainly from agriculture - and the inability of most countries to finance essential imported capital and agricultural inputs;
- Poor international commodity prices and rising prices of non-agricultural imports, especially petroleum, and
- Lack of donor commitment to provide long term rehabilitation and development aid.

Agriculture in many ways is a basic source of economic growth in most of the West African countries, it is essential that this sector be accorded the highest priority for resource reallocation and policy planning by the national Governments as well as donors.

In recent years there has been a tendency to focus on the problems of the Sahel as an isolated area, whereas in reality, from ecological, historical, contemporary political and economic reasons, the Sahel must be considered as the northern part of a larger region extending across West Africa.

This report is concerned with the assessment of the role of forage legumes in crop farming and integrated livestock production systems with regard to the sustainable use of land resources to meet the future needs of the population of the Sahelian, Sudano-Sahelian and the Sudano-Guinean regions. Countries covered in the study include: Benin, Burkina Faso, Cameroon, Chad, Cote d'Ivoire, Gambia, Ghana, Guinea, Guinea Bissau, Liberia, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo.

While the population of these countries is growing at an average rate of some 3% per annum agricultural productivity and production in many countries has fallen well short of such growth during the last two decades and this has resulted in food deficits as well as reduced exchange earnings. The livestock sector is a major component of the agricultural economy and social value system in most of these countries.

The livestock populations in the Sahelian countries were decimated by over a quarter during the 1973/74 drought and famine. The recurrence of the drought and famine again in 1984/85 has brought to the fore the plight of the livestock producers and production systems in West African countries. Until the beginning of the present century, there had been a balance between land resources and stocking rates so that people lived in harmony with their environment. However with rapid growth of human and livestock populations and deterioration of natural resources, particularly pastures and woodland areas, the pastoral systems have increasingly come into conflict with sedentary farming and urgent measures and polices are required to integrate crop and livestock production in the region, especially in the context of long term sustainability and food self-sufficiency. The fulfillment of these policy objectives will require priority attention for:

- Soil Conservation Measures: Ground vegetation cover to reduce wind and water erosion during critical months of the year;
- Soil Fertility Enhancement: Fertilizer inputs including nitrogen fixation;
- Improvement of soil organic matter content;
- Control of Diseases and Pests: Appropriate crop-mixes and sustainable agricultural activities, and
- Livestock Feed Supplies: Nutritional balanced and seasonal and spatial availability to meet the needs of livestock in nomadic pastoral areas, agro-pastoral areas, mixed farming areas and commercial ranching areas;

Forage legumes have the potential to make a simultaneous contribution to all the above aspects. For example:

- Centrosema in semi-arid areas to reduce wind erosion;
- Chamaecrista, Siratro, Forage Vigna etc. in rotation with cereal crops to control *Striga hermonthica*; also increased agricultural activity via forage legumes (e.g. Verano Stylo and Centrosema) cultivation has effect with regard to control Tsetse infestation;
- Integration of forage legumes, natural and sown pastures, crop residues and by-products in livestock feed supplies to meet seasonal and spatial demands on a regional basis.

This study is concerned with the assessment of sustainable crop, pasture and forage legumes production potential in the context of meeting the food demand-mix, including meat and milk, of the population in the years 2010 and 2025. The assessment is based on the FAO Land Resources Inventory and the Agro-Ecological Zone Methodology FAO (1978-81) and FAO (1982). The principal contribution of the study to the Agro-Ecological Zones approach (AEZ), is to extend the methodology to explicitly formulate rules for integrating crop and livestock production systems imposing relevant seasonal nutritional balances and to include forage legumes in the assessment. The optimization component allocating land resources to national objectives, building on the AEZ crop suitability assessment, has greatly enhanced and enriched with relevant sets of constraints. Details of the methodology and the land resources data base are given in the following chapters of this volume.

The present assessment is carried out at three levels of inputs and explicitly considers all relevant food crops, forage legumes and pastures (Table 1.1). In particular, the study formulates scenarios and aims to provide quantitative answers to the following:

1. What is the extent of arable land resources in each country by productivity class and by broad climatic zones: hyperarid and arid, dry semi-arid, moist semi-arid, subhumid and humid ?

2. What is the sustainable production potential of relevant food crops, pastures and forage legumes?

Table 1.1 LIST OF CROPS, FORAGE LEGUMES AND PASTURES INCLUDED IN THE ASSESSMENT.

Common Name	Scientific Name
Barley	*Hordeum vulgare*
Maize	*Zea maize*
Pearl Millet	*Pennisetum americanum*
Rice	*Oryza sativa*
Sorghum	*Sorghum bicolor*
Wheat	*Triticum aestivum*
Cowpea	*Vigna unguiculata*
Groundnut	*Arachis hypogaea*
Phaseolus Bean	*Phaseolus spp.**
Soybean	*Glysin max.*
Cassava	*Manihot esculenta*
Sweet Potato	*Ipomoea batatas*
White Potato	*Solanum tuberosum*
Banana	*Musa spp.*
Oil Palm	*Elais quineensis*
Sugarcane	*Saccharum officinarum*
Centrosema	*Centrosema pubescens*
Chamaecrista	*Chamaecrista rotundifolia*
Forage Vigna	*Vigna spp.*
Lablab	*Lablab purpureus*
Siratro	*Macroptilium atropurpureum*
Verano Stylo	*Stylosanthes hamata cv. verano*
Sown Pasture	-
Natural Pasture	-

* Includes *P. vulgaris* (Common bean), *P. lunatus* (Lima bean), *P. occineus* (Runner bean) and *P. acutfoleus* (Tepery bean).

1.2 Population

Table 1.2 shows the present population growth to the year 2010 and 2025. Nigeria is by far the most populous nation in West Africa, accounting for some 52% of the total of about 210 million in the seventeen countries considered in this study. Over the next decades the population in these countries is expected to grow at an annual rate of 2.6 to 3.2% in most countries except for Cote d'Ivoire with an estimated growth rate of 3.5% and Gambia and Guinea Bissau with growth rates of 2.4% and 2.1% respectively. This compares with the average projected growth rate of sub-Saharian Africa of 3.0% and the average global population growth rate of 1.6%.

Table 1.2 POPULATION

	Population[1] 1990 (millions)	Growth 1990-2010 (percent)	Population[1] 2010 (millions)	Growth 1990-2025 (percent)	Population[1] 2025 (millions)	AEZ Pop. Sup. Cap.[2] Low Inputs (millions)	Int. Inputs (millions)	Stationary[3] Population (millions)	Year of[3] Stationary Population
Benin	4.6	3.0	8.4	2.8	12.4	6.1	34.2	20	2035
Burkina Faso	9.0	2.8	15.5	2.7	22.6	7.0	39.8	56	2045
Cameroon	11.5	2.9	20.2	2.7	29.3	43.1	244.7	54	2035
Chad	5.6	2.6	9.3	2.4	12.9	17.0	93.6	29	2040
Cote d'Ivoire	12.0	3.5	23.7	3.3	37.9	45.3	165.5	74	2040
Gambia	0.9	2.4	1.4	2.2	1.9	1.4	4.3	5	2045
Ghana	15.0	2.9	26.6	2.7	38.0	24.1	111.3	68	2035
Guinea	5.8	3.0	10.3	2.8	15.1	12.3	56.5	33	2045
Guinea Bissau	1.0	2.1	1.5	2.1	2.7	10.3	9.0	4	2040
Liberia	2.6	3.2	4.8	3.0	12.9	57.2	47.8	9	2035
Mali	9.2	3.0	16.7	2.8	24.6	12.2	58.9	57	2050
Mauritania	2.0	2.8	3.5	2.6	5.0	1.3	4.4	11	2045
Niger	7.7	3.1	14.3	2.9	21.3	1.8	12.8	71	2055
Nigeria	108.5	3.0	197.4	2.8	285.8	53.8	235.7	382	2035
Senegal	7.3	2.6	12.4	2.4	17.1	8.3	32.3	30	2030
Sierra Leone	4.2	2.6	6.9	2.5	9.8	5.9	30.3	23	2045
Togo	3.5	3.0	6.4	2.8	9.4	3.9	20.0	20	2040
17 Countries	210.4	3.0	379.3	2.8	552.3	311.0	1201.1	946	

1 Source: UN, 1993, World Population Prospects, The 1992 Revision.
2 Source: FAO/UNFPA/IIASA, 1983, Potential Population Supporting Capacities of Lands in the Developing World.
3 Source: The World Bank, 1994, World Population Projections, 1994-95 Edition.

Such rapid population growth places enormous stress on the economy and the natural resource base as agriculture is extended into marginal lands and forests, and as the cultivation is intensified on vulnerable soils, often with inappropriate technologies and with little attention to land resources conservation and enhancement. In many of these countries agricultural systems, in the past, have involved extensive use of land, shifting cultivation with long fallow periods and limited use of manure and off-farm inputs. While arable land was abundant, this practice was viable. however, with rapid increase in populations, arable land is no longer abundant in some areas. for example, south-eastern Nigeria, western highlands of Cameroon, the Mossi Plateau of Burkina Faso, northern areas of Senegal, south-eastern areas of Niger etc. It is essential that agricultural practices are adapted to ensure long-term sustainability and viability of the natural resource base, especially in critical high population density areas.

The total population to these seventeen countries of some 210 million (1990) is projected to increase to 379 million in the year 2010 and to 552 million in year 2025. Most countries are expected to reach a stationary population by the middle of the next century. By this time the total population in the region could amount to as much as 946 million people.

At present the region has an average density of about 27 persons/sq. km, with the highest average density in Nigeria of 119 persons/sq. km and the lowest in Mauritania of 2 persons/sq. km. However in terms of potential arable land, the population density amounts to an average for the seventeen countries of 82 persons/sq. km, with Nigeria having some 176 persons/sq. km and Mauritania 71 persons/sq. km. In view of the high rate of population growth, the average population density in the region is projected to increase to some 148 persons/sq. km of arable land by the year 2010, and perhaps as much as 215 million persons/sq. km by the year 2025. By the year 2010, Nigeria will have a population density of some 321 persons/sq. km of arable land. If the present rate of land degradation and natural resources depletion continues, then the population pressure on available land will be considerably higher since it is estimated that within a 25 year period some 15 percent of the region's production potential is threatened by wind and water erosion.

Though the major obstacles to increasing agricultural production include shortage of capital investment, modern inputs, management and technical skills and research capability, the ecological limitations of the natural resource base is equally important. The ability of land to produce is limited by soil, climate and landform conditions, and land-use and management. Accordingly, knowledge on land resource endowment is an essential prerequisite to planning of optimum and sustainable land-use and subsequently sound long-term development.

The first detail assessment of the food production potential and population supporting capacity of the rainfed land resources in 117 developing countries has been reported in the FAO/UNFPA/IIASA project 'Land resources for populations of the future, FAO (1984). The results indicate that:

(i) Under the assumption of the presently practiced subsistence level of farming technology and inputs, if all the arable land area were to be cultivated with basic food crops and grassland (for livestock production); note that crop residues and by-products were not considered as feed supplies in the population supporting capacity study), then Benin, Burkina Faso, Ghana, Mali, Mauritania, Niger, Nigeria, Senegal, Sierra Leone and Togo would not have the land resources to meet the minimum food calorie and protein needs of their future populations of 2010 and beyond. Gambia would barely meet the basic food needs and only Cameroon, Chad, Cote d'Ivoire, Guinea, Guinea Bissau and Liberia could produce surplus food. For the seventeen countries as a whole the population supporting potential, at minimum intake levels, of all rainfed land resources together with planned irrigation production would amount to 311 million in comparison to the year 2010 projected population of 379 million.

(ii) If the level of farming technology and agricultural inputs were to be raised to intermediate level (for example, this would imply fertilizer input of 30-50 kg per ha) and all rainfed land resources are utilized primarily for the production of food crops and grassland (for livestock), then all countries, except Niger, would appear to have sufficient land resources to meet the basic food needs of their projected populations in the year 2010. In this case, the seventeen countries would have basic food production potential to support a total of 1201 million, somewhat higher compared to the total projected stationary population of these seventeen countries as a whole in about mid 21st century. However, at the country level, Burkina Faso, Gambia, Mauritania, Niger and Nigeria would not have adequate land resources to domestically meet the minimum food calorie needs of the stationary populations in the middle of the next century.

These results indicate that it will be necessary for most West African countries to reach at least an intermediate level of agricultural inputs and technology to ensure food self sufficiency in the year 2010 and beyond. This level of farming technology assumption implies certain utilization levels of improved seeds, fertilizers, pesticides, mechanization and farm labour, farm management practices and soil conservation measures, which in turn necessitates appropriate agricultural policies including producer prices, produce and input marketing systems, extension services etc.

Human demand for individual crops as well as meat and milk are dependent on income levels, demographic aspects etc. and hence are country specific. In West African countries, integrated crop-livestock production systems are particularly important as a source of protein food as well as being an important part of the socio-economic value systems. These considerations of crop specific food demand and integrated livestock production from pastures, crop residues and by-products and forage legumes are explicitly considered in the methodology and scenarios formulated in the present study.

1.3 Agriculture

The agriculture sector forms a major component of the economies of most countries in West Africa, Table 1.3 In 1991 it accounted for more than 50% of GDP in Ghana and between 40 and 50% of GDP in Burkino Faso, Chad, Guinea Bissau and Mali. The growth of agriculture during the period 1970-91 was, on the average, well below the rate of population increase except for Benin, Mali, Sierra Leone and Togo.

Table 1.3 **AGRICULTURE AND ECONOMY**

	GNP[1] per caput (US$) 1991	% Growth[3] Agric. 70-80 (cal)	80-91	SSR[4] Food 1961/63 (cal)	SSR[4] Food 1988/90	Growth[2] Agric. Exports 1961-91	Growth[2] Agric. Imports 1961-91	Share of Agriculture in GDP[1] 1991	Exports[2] 1989-91	Imports[2] 1989-91
Benin	389	-	4.9	109	98	-	-	36	56	20
Burkina Faso	290	1.0	3.2	110	93	-2.7	2.7	44	43	17
Cameroon	858	4.0	1.1	131	89	1.4	6.1	23	44	20
Chad	212	-0.4	3.4	133	95	-1.1	2.5	43	74	7
Cote d'Ivoire	677	2.7	-1.0	150	102	5.1	3.3	38	61	21
Gambia	367	-	-	182	73	7.2	-2.7	29	29	38
Ghana	420	-0.3	1.2	163	94	-1.0	-2.8	51	40	14
Guinea	498	-	-	98	83	-	-	32	6	20
Guinea Bissau	187	-1.2	5.0	-	-	-	-	46	72	36
Liberia	-	-	-	107	75	1.3	2.8	-	26	51
Mali	251	4.2	2.4	121	96	3.1	5.4	42	85	23
Mauritania	500	-1.0	0.7	108	93	-	-	22	8	65
Niger	303	-3.7	-	137	93	-	-	35	20	27
Nigeria	305	-0.1	3.5	116	98	-6.3	4.1	37	2	9
Senegal	736	1.3	2.7	159	80	-2.9	0.7	20	24	28
Sierra Leone	202	6.0	2.7	96	82	-4.6	2.2	-	71	11
Togo	427	1.9	5.3	122	89	2.1	7.1	33	45	20

[1] Source: World Resources Institute, World Resources (1994-95)
[2] Source: FAO, Agrostat (1993)
[3] World Bank, World development Report 1993.
[4] Self-Sufficiency Ratio. Source: FAO AT2010 (1994).

Well over 70% of the labour force derive their livelihood from agriculture in all countries except Cote d'Ivoire (65%), Ghana (56%) and Togo (68%) World Bank (1989). Most of the new entrants to the labour force in the next decade will also have little option but to seek employment in agriculture since opportunities for growth in the non-agriculture sector are very limited in most countries.

Agriculture also accounts for a major share of export earnings, for example, more than 70% in the case of Chad, Guinea Bissau, Mali and Sierra Leone (see Table 1.3) and this is often concentrated in one or two crop commodities: Benin (cotton, 40% of total export earnings), Burkina Faso (cotton, 25%) Cameroon (cocoa and coffee 20%), Gambia (groundnuts, 60%), Ghana (cocoa, 50%), Cote d'Ivoire (cocoa and coffee 50%), Mali (cotton 25%), Senegal (groundnuts 20%). For few countries in West Africa, endowed with mineral wealth, the non-agricultural export earnings also accrue to raw material exports rather than processed goods: Cameroon (petroleum, 45% of total export earnings), Liberia (iron ore 30%), Niger (uranium, 80%), Nigeria (petroleum 95%), Senegal (phosphates, 20 %) and Togo (Phosphates, 50%).

During the period 1961 to 1991 the agriculture exports of Burkina Faso, Chad, Ghana, Nigeria, Senegal and Sierra Leone declined. Also, during this period agriculture imports, primarily basic food commodities, grew in most countries, except Ghana and Gambia where a decline of was reported.

The poor performance of agriculture in many countries is due to a number of environmental factors which have contributed to low yields and crop acreages and lower livestock productivity and animal herd size. Among factors that have been highlighted in numerous national and international reports, desertification, deforestation, overgrazing, soil erosion etc., have resulted in setting up of several commissions, projects and guidelines. In seeking urgent solutions, there has been a tendency in a number of countries to launch alternative programmes to cope with reductions in fallow periods as a means to achieving food security objectives. However, this practice has not been sustainable in the long term because means of improving soil fertility and resource conservation were not incorporated.

It is particularly worrying that there have been frequent periods in recent years of a very substantial decrease in the level of food self- sufficiency in most West African countries. For example, comparing the self- sufficiency ratio in 1961/63 and 1988/90, Table 1.3, the declines were by more than 40% in the case of Gambia, Ghana and Senegal. This unsatisfactory performance of the food sector at the national level has also to be considered in the context of the country's most vulnerable groups, especially the poor in the urban areas and the pastoral population as well as the sedentary farmers in the semi-arid and arid areas. Many people displaced by the drought an famine conditions in 1973/74 and 1984/85 have sought refuge in the urban areas despite little access to employment and income earning opportunities.

Table 1.4 shows the nutritional situation in 1969/71, 1979/81 and 1988/90 in terms of per capita daily calorie intake for each of the countries of the study. The data show that in seven countries there has been a decline in calorie intake, especially Chad and Sierra Leone, where estimated average intake levels are well below 2000 calories per capita per day. This average situation at the country level has serious implications for the poorest groups in society. The consumption of livestock products has declined significantly in ten of the seventeen countries over the period 1969/70 to 1988/90.

1.4 Forage Legume in Land-Use Intensification

Food security is a primary objective of all developing nations with burgeoning human populations. However it is difficult to achieve because of inherent conflict between increasing food production and maintaining the sustainability of farming systems. At low levels of population soil fertility can be restored by allowing land to lie fallow at appropriate frequencies. But this becomes less possible as more land is required to meet immediate food needs.

Table 1.4 **DAILY CALORIE CONSUMPTION (Kcal/cap/day)**

	Total Daily Calorie Consumption				Calories from Livestock			
	1969/71-1988/90 (% incr./yr)	1969/71	1979/81	1988/90	1969/71-1988/90 (% incr./yr)	1969/71	1979/81	1988/90
Benin	0.5	2149	2145	2383	0.5	94	101	104
Burkina Faso	1.3	1777	1815	2267	0.3	93	89	99
Cameroon	-0.2	2313	2266	2208	1.5	113	109	151
Chad	-1.1	2147	1710	1735	-0.3	167	168	158
Cote d'Ivoire	0.3	2420	2844	2569	-0.1	149	182	146
Gambia	0.2	2203	2101	2290	0.6	123	121	137
Ghana	-0.2	2227	1972	2144	-1.1	132	102	106
Guinea	0.2	2172	2268	2242	0.6	50	82	82
Guinea Bissau	0.4	2073	2057	2235	-0.9	192	169	161
Liberia	0.1	2216	2400	2259	-1.0	102	105	85
Mali	0.6	2000	1898	2259	-1.5	265	240	197
Mauritania	1.2	1944	2081	2447	-1.3	602	531	466
Niger	0.6	1989	2223	2240	-2.5	183	169	113
Nigeria	-0.3	2340	2128	2200	-1.6	77	100	57
Senegal	-0.3	2471	2415	2322	0.1	210	180	213
Sierra Leone	-0.5	2096	2096	1899	-1.2	84	97	67
Togo	-0.2	2377	2266	2268	1.8	74	71	103

Source: FAO, Agrostat. (1993)

Food production can be increased by employing higher levels of external inputs such as fertilizer and pesticides, but this approach has particular risks and limitations in the context of smallholder farming systems. Ruminant livestock, cattle, sheep, and goats, can convert poor quality grasses, crop residues, weeds and agro-industrial by-products into high food-quality milk and meat products. In addition to meeting protein and energy needs, recent studies have re-emphasized the importance of micro-nutrients derived from livestock food products in the development of human learning skills. Livestock also contribute affordable draught power and manure that can be used strategically to sustain soil fertility.

It is hypothesized that; in West Africa the processes of intensification of smallholder production will be most sustainable when crop and livestock production are fully integrated. The introduction of forage legumes is a key to the integration process because they provide benefits to both crops and livestock. They have the capability to conserve and enhance arable land resources and also provide high quality feed for livestock.

When forage legumes are introduced in the rotation of annual crops, they provide soil nitrogen by biological fixation and raise organic matter levels (Mohamed Saleem and Otsyina, 1986; Tarwali, 1991) thus improving soil structure and fertility and break disease cycles (Hartmaus et al, 1982) (e.g. of *Striga hermonthica*, a semi-parasitic weed which attacks cereal and legume crops). Forage legumes can also help to control soil erosion by providing more effective ground cover and reduce soil erodibility. Further they add flexibility to cropping systems by offering additional options such as hay production or grazing.

Smallholder mixed cropping and fallowing can be flexible, and responsive to changing environments and new technologies. Maize and cassava are examples of relatively recent introductions that were readily adopted and spread across West Africa. However, despite demonstrated willingness to change, smallholders are not adopting new technologies fast enough to keep pace with the growing demands of food.

The natural response to increasing demand has been to open up new land and decrease the period of fallowing. This practice is not sustainable because the land area is finite. It has serious consequences for soil degradation, especially when it also involves encroachment into seasonable vital grazing land such as the inland valleys (bas fonds). The consequences can be devastating in two respects: food crop yields from continuously cropped lands are generally poor compared to labor expended on cultivation, and, perhaps more importantly, such encroachment increases grazing pressures and overgrazing leading to further environmental degradation.

Low input technologies are required, that can increase food production from crops and livestock and sustain the productivity of the land that is regularly cultivated. In this context that the potential of forage legumes in West African farming systems is considered here.

Proper soil management aims at preserving appropriate and sustainable levels of:

(a) In soil profile

- soil organic matter and cation exchange capacity
- soil bulk density
- soil moisture distribution and retention
- soil nitrogen concentrations
- soil minerals
- soil micro-organisms activity

(b) At soil surface

- soil surface erosion
- soil surface temperature

A natural fallow takes several years to restore the above factors, because of the slow sequence of plant successions. The increasing tendency to reduce fallow periods is for most part caused by increasing scarcity of unused land. It can also be due to the difficulty of opening up old fallow for cropping. Preference to re-use used crop land, rather than open up old fallow, is common when the urban drift of young people is aging the farming population. This is a serious problem because a crop-free period is essential to all low input cropping systems on tropical soils (Tarawali, et al., 1987).

Despite the evident advantages, some traditional farming practices do not integrate crop and livestock very well because they were mainly developed by different communities. The research and extension communities in West Africa have been equally prone to deal with livestock and cropping systems quite separately. Livestock owners traditionally depend on open access to crop fields after harvest and to communal grazing land. Thus they have no incentive to invest in the soil conservation even though they are under increasing pressure as cropping spreads into areas that are vital grazing resources. For example increased cultivation of inland valleys (bas fonds) reduces the amount of high quality grazing that can be found through the dry season on the edge of the receding water surface.

The International Livestock Centre for Africa (ILCA) did several years of research in West Africa towards ameliorating the shortage of protein in the feed available to ruminant livestock, particularly in the subhumid zone. This led to technologies for growing forage legumes for strategic feed suplementation. Incorporation of forage legumes into cropping systems also benefits soils improving some of the physical, chemical and biological properties listed above. Grain legumes can have similar but smaller effects on soil fertility.

At various times during the past decades forage legumes from Australia and Latin American countries have been tested within West African environments. The prime objective of such introductions was to improve the quality of feed for the ruminant livestock that depend on seasonally variable grass dominated grazing lands. Legumes having a C_3 photosynthesis pathway grow slowly compared to C_4 grasses. But legumes meet their nitrogen needs by establishing an association in their root nodules with native or inoculated rhizobia. This enables them to provide more protein to livestock diets than the fast maturing grasses. Although many studies emphasize the potential contribution of legumes in ruminant nutrition, there has not been any significant adoption of forage legumes in the production systems of the livestock owners. Technologies prescribed for growing forages were often found inappropriate and in many countries interest in cultivated forage legumes, stagnated.

Since ILCA started research in the Nigerian subhumid zone in 1979, it has been able to demonstrate simple technologies for growing and utilizing forage legumes by the small holders producers. For example, Stylosanthus established on cattle-trampled plots near homesteads of the livestock owner (fodder banks) for strategic feeding of livestock during times of stress has produced significant impact on the productivity of the smallholders herds.

Many years of on-station and on-farm experimentation also have shown that areas have been for 2-3 years on reverted to cereal production have significantly higher yields than those that have been continuously cropped or even under natural fallow. The grain yield improvement results from the rapid accrual of benefits from the legumes in respect of positive soil nitrogen balance, moisture dynamics and physico-chemical properties. This would seem to provide a much needed means for maintaining or enhancing fertility so that productivity can be raised in sustainable ways. However adoption will continue to be slow unless the full implications are expressed in terms that are meaningful to national planners and development agencies as well as extension agents in order to encourage them to create enabling environments for rapid adoption of appropriate technologies. This has led to this renewed attempt at assessing the potential role of forage legumes in the production systems, especially within the context of smallholder West African farmers who strive to support increasing food demands with constrained land and material resources. There is compelling research evidence from the work done at ILCA and NARS, that forage legumes have a vital role to play in helping to activate this objective but implications have not before been determined on national or regional scales.

1.5 The Joint ILRI, FAO, IIASA Study

This joint ILRI, FAO and IIASA study to assess the potential role of forage legumes in the cropping systems of West Africa countries comprises evaluations of:

(a) potential integration of compatible crop, pasture and livestock production practices and sustainability of the resource base;

(b) potential improvement of overall crop and livestock productivity, and

(c) potential impact on livestock carrying capability and human supporting capacities, within the context of national and regional land use development.

This study brings together ILCA's multilocational forage research with FAO's AEZ methodologies for quantifying land potentials and IIASA's capabilities in system analysis and modeling. The work has involved the following specific activities:

Land suitability and productivity assessments of six forage legumes (Verano Stylo, Chameacrista, Centrosema, Lablab, Siratro, and Forage Vigna), natural and Sown Pastures, and main crops of the Region;

Assessment of integrated crop-livestock models, taking into account seasonal and spatial availability and requirements of feed (quantity and quality) supplies from natural and sown pastures, forage legumes as well as crop residues and by-products. Ruminant livestock productivity is assessed in terms of 26 possible crop-livestock systems, at traditional, feed supplemented and improved levels.

Formulation and incorporation of a national level optimization function, allocating land resources in each country according to national level objectives and constraints, e.g. commodity specific demand targets, livestock feed balances and livestock distribution.

This Volume describes with the AEZ land resources data base used in the study (Chapter 2). Chapter 3 deals with land suitability assessments, and involves agro-climatic and agro-edaphic assessments. Input data and results of the suitability assessment for forage legumes, grasses and crops considered in the study are presented in Appendix 3. Chapter 4 presents an assessment of primary productivity of land , taking into account multiple cropping, fallow period requirements and effects of soil erosion. The results on primary productivity form the input into the assessment of secondary production and land use optimization models presented in Volume 2.

1.6 Agro-ecological Zones (AEZ) Methodology for Primary Land Productivity Assessment

This Section summarizes the steps involved in the compilation of an AEZ land resources data base and in the assessment of primary land productivity based on potential integration of food crops, forage legumes and grasses, in sustainable production systems.

The methodology is schematically presented in Figure 1 and comprises the following activities:

LUT and Ecological Adaptability

(i) selection and formulation of food crop, forage legume and grass land utilization types (LUTs);
(ii) determination of ecological adaptability of the selected food crops, forage legumes

and grasses;

Land Resources Inventory

(iii) selection of soil and terrain resources inventory (FAO/Unesco Soil Map of the World);
(iv) compilation of climatic resources inventory (from climatic data);
(v) selection of ecosystem inventory (Olson World ecosystems);
(vi) selection of protected areas inventory (IUCN);
(vii) storage and overlay in GIS the inventories of soil & terrain resources (iii), climatic resources (iv), protected areas (v) and ecosystems (vi);
(viii) compilation of a soil and terrain map unit composition database (quantification of soil and terrain associations in terms of soil units, soil phases, soil textures, slopes etc.);
(ix) combining the overlaid spatial information with the soil and terrain map unit database i.e. creation of agro-ecological cells (AEZ cell) representing unique units in terms of the soil and terrain, climate, protected areas, and ecosystems attributes;
(x) creation of geo-referenced Land Resources Inventory (LRI) database;

Land Suitability

(xi) calculation of constraint-free biomass and yield based on crop forage genetic parameters and prevailing temperature and radiation conditions;
(xii) formulation of agro-climatic suitability;
(xiii) formulation of agro-edaphic suitability;
(xiv) matching of agro-climatic and agro-edaphic suitabilities to the land resources inventory;
(xv) creation of a geo-referenced land suitability data base by LUT and AEZ cell;

Primary Land Productivity

(xvi) incorporation of yield effects of intercropping and sequential cropping on land productivity;
(xiii) incorporation of effects of fallow requirements on land productivity under natural and sown fallow systems;
(xviii) quantification of soil loss due to water erosion, and its effects on land productivity, and
(xix) creation of primary land productivity database, for assessments of secondary productivity and for land use optimization (see Volume 2).

Figure 1.1 AEZ PRIMARY PRODUCTIVITY ASSESSMENT

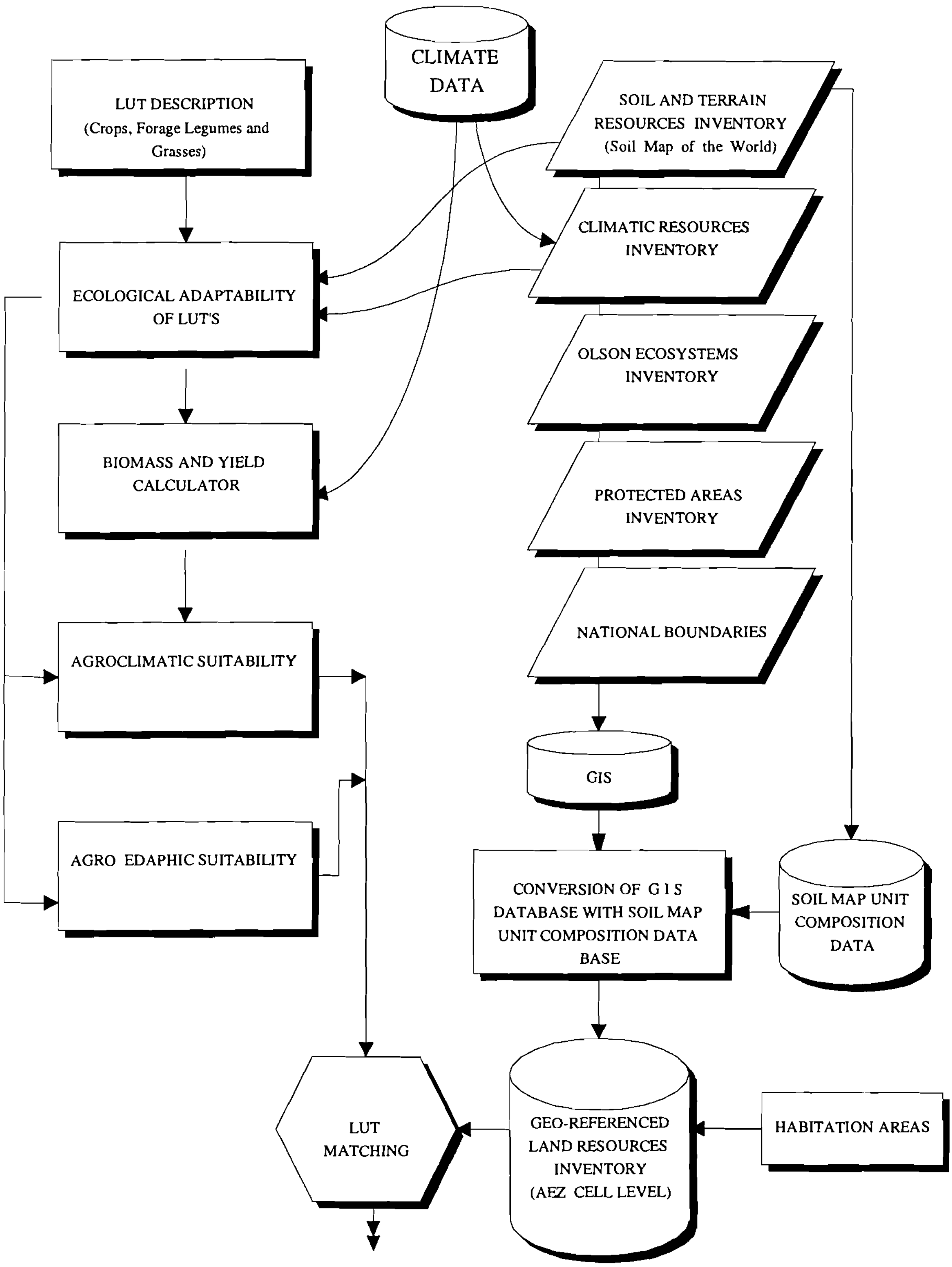
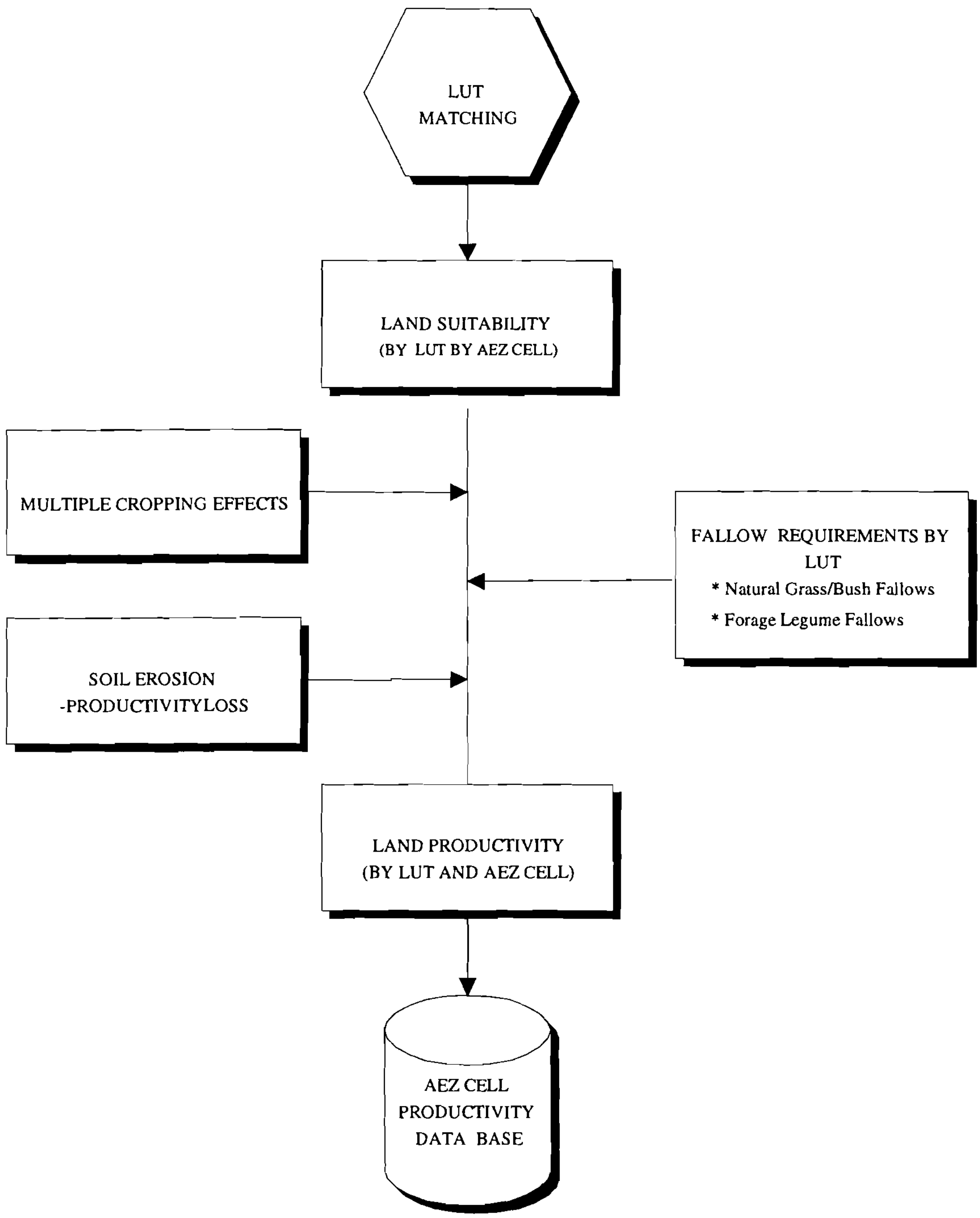


Figure 1.1 Continued



CHAPTER 2: LAND RESOURCES

2.1 Introduction

The FAO Agroecological Zones (AEZ) 1:5 million scale land resources inventory was created for the study of the production potential of the land resources of the developing world (FAO 1978-1981). Soil and climate data were combined to yield a quantified thematic inventory of agro-ecological cells.

Inherent in the method of compiling a quantified land resources inventory is the generation of a climatic inventory of moisture and thermal zones. The climatic inventory is superimposed onto the soil and terrain inventory to produce a land resource inventory which is described in this chapter. Additionally information on ecosystems, protected areas and human settlement areas is included.

2.2 Climatic Resources

Temperature and water are the major climatic factors that govern distribution (both in space and time) of crops. In combination with solar radiation, these climatic factors condition the net photosynthesis and allow the crops to accumulate dry matter (and accomplish the successive development stages) according to the rates and patterns which are specific to cultivated plants.

While present knowledge does not allow full quantification of all agronomic consequences of climate in relation to crop adaptability and production, a number of crop/climate relationships can be quantified in order to allow:

(i) an assessment of the influence of climate on spatial and temporal distribution of crops;

(ii) the production that can be attained under conditions that are free of constraints.

The reference growing period has been used as a framework for the assessment of climatic resources. It is defined as the period in which temperature and moisture permit crop growth. To take into account crop temperature requirements, prevailing temperature regimes during the growing period have been inventoried by identification of thermal zones.

The inventory of climatic resources allows:

(i) differentiation into thermal zones reflecting the geographical distribution of the prevailing temperature regimes;

(ii) differentiation into length of growing period zones, reflecting prevailing moisture regimes;

(iii) quantification of potential yields (crops, forage legumes and grasses) that can be attained under constraint-free conditions;

(iv) assessment of agro-climatic constraints to take into account yield losses likely to occur.

The usefulness of any climatic inventory, for predicting agro-climatic suitability for crop growth, is dependent on how well the climatic requirements of crops can be matched with the climatic parameters used in the inventory. Accordingly data on the climatic requirements of crops is an essential prerequisite to the compilation of climatic inventories.

To aid the compilation of such data on climatic requirements, crops have been classified into climatic adaptability groups according to their fairly distinct photosynthesis characteristics. Four crop groups have been formulated (Kassam, Kowal & Sarraf 1977) for the agro-climatic suitability assessments, namely:

Group I: e.g., wheat, barley, highland phaseolus bean, white potato, with a C_3 photosynthesis pathway, with an optimum temperature for maximum photosynthesis of 15-20°C and adapted to operate under moderately cool and cool conditions (mean daily temperature 5-20 °C).

Group II: e.g., soybean, cotton, sweet potato, cassava, groundnuts, rice, forage legumes with a C_3 photosynthesis pathway, with an optimum temperature for maximum photosynthesis of 25-30 °C and adapted to operate under warm conditions (mean daily temperature > 20°C).

Group III: e.g., pearl millet, lowland sorghum, lowland maize, sugarcane, grasses with a C_4 photosynthesis pathway, with an optimum temperature for maximum photosynthesis of 30-35 °C and adapted to operate under warm conditions (mean daily temperature > 20°C).

Group IV: e.g., highland sorghum, highland maize, and grasses with a C_4 photosynthesis pathway, with an optimum temperature for photosynthesis of 20-30°C and adapted to operate under moderately cool conditions (mean daily temperature 15-20 °C).

The climatic inventory characterizes both heat and moisture conditions. This was achieved through the concept of reference length of growing period. A moisture supply from rainfall of half, or more than half, potential evapotranspiration has been considered to permit crop growth. Further mean daily temperatures greater than 5°C have been considered as being conducive to growth.

Quantification of the heat attributes during the growing period is achieved by classifying thermal zones defining the actual temperature regime during the growing period. Each of the thermal zones recognized is thus defined. The temperature thresholds used in these definitions accord with those differentiating the four crop groups and therefore allow matching of the temperature requirements of the crops with the temperature parameters used in the climatic inventory. In this way the crops which can be considered as 'possible' for growth in the different thermal zones are distinguished. Table 2.1 presents the seven thermal zones defined for the West African Region and the crop groups considered in each of these.

Quantification of moisture conditions in the growing period is based on water balance model comparing precipitation (P) with potential evapotranspiration (PET). The model allows for soil moisture storage capacity and in the model, a reference 100 mm soil moisture storage has been assumed. Accordingly the time to evapotranspire this 100 mm of storage water (or less if 100 mm excess precipitation is not available) has been included in the waterbalance.

TABLE 2.1 CHARACTERISTICS OF THERMAL ZONES

Climate	Thermal Zone	24-hour mean temp. regime (°C) during growing period	Suitable for consideration (during the growing period) for crop group
Tropics			
Monthly mean temperature, corrected to sea level, above 18°C	Warm tropics	More than 20	II and III
	Moderately cool tropics	15 - 20	I and IV
	Cool tropics	5/10 - 15	I
Subtropics			
One or more months with monthly mean temperature, corrected to sea level below 18°C	Warm subtropics (summer rainfall)	More than 20	II and III
	Moderately cool subtropics (summer rainfall)	15 - 20	I and IV
18°C but all months above 5°C	Cool subtropics (summer rainfall)	5/10 - 15	I
	Moderately cool and cool subtropics (winter rainfall)	5/10 - 20	I

Four types of growing periods have been recognized:

Normal growing period: The average monthly rainfall exceeds for some time during the year the average monthly PET (humid period). The beginning of a normal growing period is defined as the point in time where the rainfall exceeds 0.5 PET; the end is defined as the time when rainfall plus soil moisture storage drops below 0.5 PET.

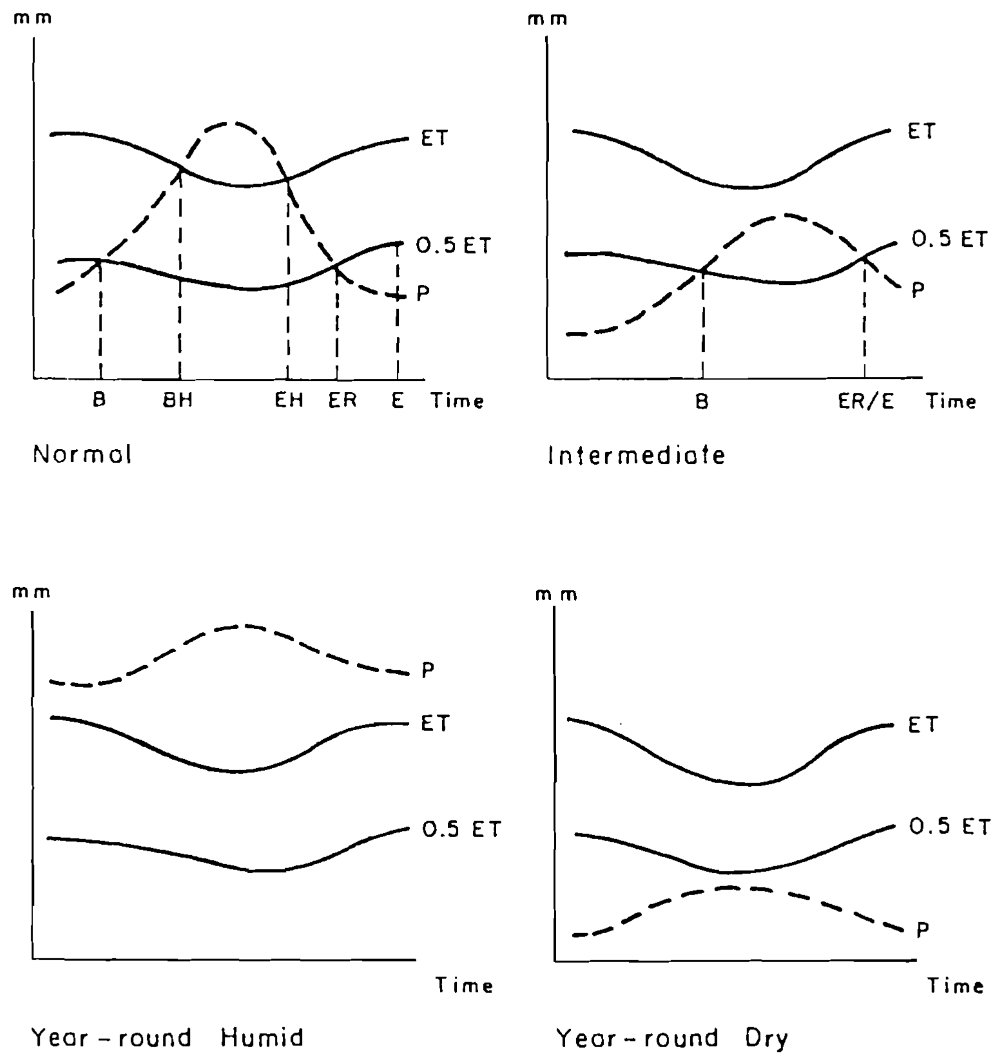
Intermediate growing period: Throughout the year, the average monthly rainfall does not exceed PET, but it does exceed 0.5 PET. The beginning and the end of such intermediate growing period are defined as the points in time where P exceeds respectively falls short of 0.5 PET.

All year round humid growing period: The average monthly rainfall, for every month of the year, exceeds the full rate of the average monthly PET.

All year round dry period: The average monthly rainfall every month of the year is lower than 0.5 PET.

The four growing period types are schematically presented in Figure 2.1. A generalized page size map of the climatic inventory for West Africa is presented in Figure 2.2, and the extents of each climatic zone for the region are given in Table 2.2.

FIGURE 2.1 SCHEMATIC PRESENTATION OF TYPES OF GROWING PERIODS



B - Beginning of growing period
BH - Beginning of humid period
EH - End of humid period
ER - End of rainy season
E - End of growing period

P - Precipitation
ET - Potential evapotranspiration

2.4 Ecosystems

The Ecosystems Inventory was derived from Olson World Ecosystems. This data base consists of a digital raster data on a 10 minute geographic grid (Olson 1989-91). It contains world-wide 74 categories which have been condensed for the purpose of this study into ten broad ecosystems as follows:

1. Desert
2. Grassland
3. Shrub land/Low Forest associations
4. Forest
5. Farmland/Forest associations
6. Farmland
7. Farmland (with irrigation)
8. Swamps and marshes
9. Mangrove/mudflat
10. Others

The ecosystems inventory has been integrated in the FAO/AEZ database by GIS overlaying. In this way each polygon of the FAO/AEZ database was characterized in terms of the ten ecosystem categories. Figure 2.4 presents a generalized map of ecosystems and Table 2.3 presents the occurrence of the above ecosystems for each of the countries of West Africa.

Table 2.3 EXTENTS ECOSYSTEMS (1000 ha)

COUNTRY	ECOSYSTEMS										
	1 Desert	2 Grass	3 Shr/Fo	4 Forest	5 Frm/Fo	6 Frm/Dl	7 Frm/Ir	8 Swamp	9 Mangr	10 Other	Total
Benin	0	6935	0	0	1857	2244	0	22	48	158	11263
Burkino Faso	0	21392	75	2359	0	3565	0	29	0	6	27425
Cameroon	0	10248	633	25020	4326	6273	0	336	96	118	47229
Chad	66010	42776	7524	3946	0	3325	2646	724	2	90	127043
Cote d'Ivoire	0	8862	7	16179	1394	4853	0	15	272	296	31959
Gambia	0	20	0	501	31	186	180	0	68	82	1051
Ghana	0	9942	1	8371	1519	2114	0	11	219	464	22642
Guinea	0	13502	2	9771	400	286	0	40	258	322	24581
Guinea Bissau	0	509	0	2072	0	0	0	1	557	470	3609
Liberia	0	132	4	7261	629	2649	0	7	424	32	11137
Mali	57929	23358	16084	3541	0	13718	4293	4339	0	646	123907
Mauritania	80349	9305	6421	0	0	0	4901	28	0	1546	102553
Niger	79067	32142	11592	2801	0	0	0	497	0	279	126377
Nigeria	0	30219	1982	16269	4704	35161	0	690	1370	658	91053
Senegal	0	7267	6	1923	390	5732	3041	132	422	653	19565
Sierra Leone	0	605	3	4594	701	671	0	3	247	344	7168
Togo	0	2757	4	1583	967	225	0	10	54	65	5664

2.5 Protected Areas

In West Africa some 20 million ha of land (4% of total land area) are designated as protected areas in which agriculture, among other economic activities is prohibited by law. The protected areas represent the Classes I, II, IV and VIII of the categories for Conservation

Management of the IUCN's 1990 List of National Parks and Protected Areas. Normally these areas are national parks, conservation forest and wildlife reserves. In addition to the IUCN registered protected areas, a number of unclassified protected areas have been included. A generalized page size map of the protected areas in West Africa is presented in Figure 2.5. Table 2.4. provides by country extents of the protected area.

Table 2.4 EXTENTS OF PROTECTED AREAS AND HUMAN SETTLEMENT AREAS (1000 ha)

COUNTRY	PROTECTED AREAS							HUMAN SETTLEMENT AREAS			
	I	II	IV	VIII	Others	Total	%	2010	%	2025	%
Benin	0	872	7	1774	0	2653	23	395	3.5	443	3.9
Burkino Faso	0	443	2690	0	730	3863	14	883	3.2	990	3.6
Cameroon	0	1056	1069	0	<1	2125	4	1388	2.9	1565	3.3
Chad	0	408	155	0	80	643	<1	1539	1.2	1906	1.5
Coted'Ivoire	56	1866	73	0	61	2056	6	1118	3.5	1287	4.0
Gambia	0	11	0	0	0	11	1	44	4.2	49	4.6
Ghana	36	1090	24	331	18	1499	7	909	4.0	1019	4.5
Guinea	100	28	0	784	131	1043	4	717	2.9	812	3.3
Guinea Bissau	0	0	0	0	0	0	0	105	2.9	115	3.2
Liberia	0	110	0	0	0	110	1	328	2.9	374	3.4
Mali	0	0	0	0	0	0	0	2195	1.8	2677	2.2
Mauritania	0	486	0	0	0	486	<1	696	0.7	924	0.9
Niger	1364	231	7144	0	0	8739	7	2025	1.6	2521	2.0
Nigeria	0	584	567	184	1641	2976	3	4484	4.9	5202	5.7
Senegal	0	856	1295	0	0	2051	11	652	3.3	719	3.7
Sierra Leone	0	0	80	0	0	80	1	271	3.8	302	4.2
Togo	0	0	0	0	501	501	9	225	4.0	254	4.5
Region Total	1557	8041	13105	3072	3162	28937	4	24001	3.1	27001	3.4

Note: Percentages relative to total Country extents

The IUCN categories and management objectives of protected areas are as follows:

Class I *Scientific Reserve/Strict Nature Reserve*; to protect nature and maintain natural processes in an undisturbed state in order to have ecological representative examples of the natural environment available for scientific study, environmental monitoring, education, and for the maintenance of genetic resources in a dynamic and evolutionary state.

Class II: *National Park*; to protect natural and scenic areas of national or international significance for scientific and recreational use.

Class IV: *Managed Nature Reserve/Wildlife Sanctuary*; to assure the natural conditions necessary to protect nationally significant species, groups of species, biotic communities, or physical features of the environment where these require specific human manipulation for their perpetuation.

Class VIII: *Multiple-Use Management Area/Managed Resource Area*; to provide for the sustained production of water, timber, wildlife, pasture, and outdoor recreation, with the conservation of nature primarily oriented to the support of economic activities (although specific zones may also be designed within these areas to achieve specific conservation objectives.

2.6 Human Settlement Areas

The estimation of the extents of human settlement areas (residence and infrastructure) are based on a function[1] that relates non agriculture land use per person to population density, (the higher this density the lower the area per person used for non agricultural purposes). This function (FAO/IIASA 1994) was subsequently applied to the agro-ecological zones of each country in West Africa. For this estimates of population density by agro-ecological zones were extrapolated from estimates used in the FAO/UNFPA/IIASA 1978-1984 project on Land Resources for Populations of the Future to year 2010 and year 2025 populations, resulting in human settlement areas as required by 2010 and 2025 (Table 2.4).

2.7 Land Resources Inventory

Superimposition of the climatic inventory on the Soil Map of the World (GIS overlay) allows the creation of geo-referenced agroecological zones within which soil and climatic conditions are known and quantified. The agro-ecological zones polygons are broken down by slope and texture class and phase (soil map unit composition) as they occur in each length of growing period zone, in each thermal zone and in each country. In this way a data base of homogeneous areas in terms of climate, soil and terrain conditions is created. These unique units are referred to as agro-ecological cells (AEZ cells). The collection of AEZ cells constitutes the Land Inventory.

Additional information on ecosystems, protected areas and human settlement has been incorporated in the land inventory through GIS overlay (ecosystems, protected areas) and procedures (human settlement areas). In this way each AEZ cell has been characterized for prevailing ecosystems, protected areas and human settlement area.

The land inventory of West Africa records total extents of 44,039 AEZ cells in 3,623 GIS polygons. The components of AEZ cells are given in Table 2.5.

Table 2.5 COMPONENTS OF AEZ CELL

* Country (17 Countries)
* Thermal Regime (7 zones)
* Length of Growing Period (13 zones)
* Soil Association (655 map units)
* Soil Unit (73 types)
* Soil Texture (3 classes)
* Terrain slope (6 classes)
* Ecosystem (10 classes)
* Protected Area (five classes)
* Human Settlement Area (in percentage of AEZ cell)
* Extent (ha)

1 The function used is based on district data of Kenya. This function reads:
$HA = 1/(4.2644 + 28.182*PD) + 0.0074165$
where: HA = human settlement area (ha/person) and PD = population density (persons/ha).

CHAPTER 3: LAND SUITABILITY

3.1 Introduction

The AEZ approach to land suitability assessment follows the principles and methodologies presented in FAO (1978 and 1980) for crops, and FAO/IIASA (1991) for natural grasses. For this West African study, four working papers were prepared earlier on land suitability assessment for 16 crops, six forage legumes and pasture (Kassam, van Velthuizen and Saleem 1988a, 1988b, 1990 and 1991).

This chapter presents the agro-climatic and agro-edaphic suitability and the assessment of land suitability for six forage legumes[1] pasture[2] at three levels of input circumstances.

The procedures for assessing land suitability as set in the FAO/AEZ system comprises the following activities:

(i) selection and definition of land utilization types (e.g., forage crop type and produce; cropping season; cultivation type; inputs level; moisture supply type; production system);
(ii) determination of climatic requirements of the forage species/land utilization types;
(iii) determination of edaphic requirements of the forage species/land utilization types;
(iv) formulation of agro-climatic suitability;
(v) formulation of agro-edaphic suitability, and
(vi) matching of agro-climatic and agro-edaphic suitabilities of forage species to the land resources inventory (agro-ecological cell level).

The above activities are described in the following sections.

3.2 Land Utilization Types

Combined descriptions of the forage species, produce, inputs, technical know-how, etc., form the bases of the definition of the land utilization types (LUTs) employed in the assessment. Detailed definition of the LUTs applicable to a national/regional land evaluation is difficult because of wide variation in the socio-economic and management factors within and across countries.

For the assessment of land suitability for forage legumes and sown pasture, generalized LUTs have been considered. These are based on sole cropping at three levels of inputs[3].

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1 The forage legumes are: verano stylo (*stylosanthes hamata cv. verano*), Chamaecrista (*chamaecrista rotundifolia*), centrosema (*centrosema pubescens*) siratro (*macroptilium atropurpureum*) lablab (*lablab purpureus*) and forage vigna (*vigna spp.*)

2 The following grasses are considered to make up sown pasture: Jaragna grass (*Hyparrhenia spp.*), Gamba grass (*Andropogon gayanus*), Rhodes grass (*Chloris gayana*), Guinea grass (*Panicum maximum*), Napier grass (*Pennisetum purpureum*), Pangola grass (*Digitaria decumbens*), Star grass (*Cynodon spp.*).

3 At present most West African countries are at an average level of fertilizer use which corresponds with a level between the low and intermediate level inputs.

Under the low input, traditional management assumption, the farming system is subsistence based. Production is based on a production cycle of three years, on labour intensive techniques with hand cultivation without fertilizer and biocide application[4].

Under the intermediate input, improved management assumption, the subsistence based farming system is partly market-oriented. Production is based on a production cycle of three years, on labor intensive techniques with hand tools and animal traction and on sub-optimum use of fertilizer and biocide.

Under the high input, advanced management assumption, the farming system is largely market-oriented. Production of surplus beyond subsistence needs is a management objective. Production is based on a production cycle of two years, on low labour input, on mechanical cultivation and optimum use of fertilizer and biocide.

Pertinent to the definition of the three LUTs are the facts that the forage legumes and sown pasture are grown for green fodder production for dry season grazing in situ, and that fire and erosion hazards are minimal due to good management.

An overview of the attributes for the three levels of inputs and management circumstances are presented in Table 3.1.

3.3 Climatic Adaptability

The concepts and principles of crop climatic adaptability relevant to land suitability assessment have been described in detail in FAO (1978).

Forage legumes and sown pastures have requirements for photosynthesis and phenology, both of which bear a relationship to biomass production. The rate of photosynthesis and biomass production are directly related to photosynthetic capacity (unit area efficiency x size of photosynthetically active area) and its response to temperature and radiation.

Within any suitable length of growing period the temperature and photoperiodic regimes together govern which forage species can be grown. When the climatic phenological requirements are met, then the temperature and radiation regimes together set a limit to biomass productivity.

To assess forage legumes and sown pasture for its climatic suitability, it is necessary to prepare an inventory of climatic adaptability requirements for both photosynthesis and phenology. Table 3.2 gives the climatic adaptability attributes of forage legumes and sown pasture.

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4 A standard definition of low inputs does not include any application because fertily would be maintained through natural fallows.

Table 3.1 ATTRIBUTES OF THE LAND UTILIZATION TYPES CONSIDERED FOR FORAGE LEGUMES AND SOWN PASTURE

Attribute	Low Inputs	Intermediate Inputs	High Inputs
Crop and produce	Rainfed production of forage legumes and sown grasses for fodder grazed in situ during the dry season		
Production method	Rainfed production, sole cropping for a minimum period of three years	Rainfed production, sole cropping for a minimum period of three years	Rainfed production, sole cropping for a minimum period of two years
Market orientation	Subsistence production	Subsistence production plus commercial sale of surplus	Commercial production
Capital intensity	Low	Intermediate with credit on accessible terms	High
Labour intensity	Moderate to high, including uncosted family labour	Medium, including uncosted family labour labour	Low, family labour costed, if used
Power source	Manual labour with hand tools	Manual labour with handtools and/or animal traction with improved implements and some mechanization	Complete mechanization
Technology employed	Improved cultivars. No (or markedly insufficient) fertilizer except minimum amount (10-15 kg) of P, no chemical pest, disease and weed control, fallow periods for both water and nutrient accumulation	Improved cultivars. Some fertilizer application and some chemical pest, disease and weed control, fallow periods for both water and nutrient accumulation	Improved cultivars. Adequate fertilizer application and chemical pest, disease and weed control, fallow periods for water accumulation where necessary
Infrastructure requirement	Market accessibility not essential; no or inadequate advisory services	Some market accessibility and extention services	Communications and market accessibility essential; high level of advisory services and application of research findings
Land holding	Small, fragmented	Small, sometimes fragmented	Medium and large consolidated
Income level	Low	Moderate	High

Note: No production involving irrigation or other techniques using additional water. No flood control measures.

3.4 Edaphic Adaptability

In order to assess suitability of soils for forage species production, soil requirements for these species must be known. Further these requirements must be understood within the context of limitations imposed by landform and other features which do not form part of soil composition but may have a significant influence on the use that can be made of the soil.

The basic soil requirements of plants in general, may be summarized under the following headings, related to internal and external soil properties:

a. Internal requirements:

- the soil temperature regime, as a function of the heat balance of soils as related to annual or seasonal and daily temperature fluctuations;
- the soil moisture regime, as a function of the water balance of soils as related to the soil's capacity to store, retain, transport and release moisture for plant growth, and to the soil's permeability and drainage characteristics;
- the soil aeration regime, as a function of the soil air balance as related to its capacity to supply and transport oxygen to the root zone and to remove carbon dioxide;
- the natural soil fertility regime, as related to the soil's capacity to store, retain and release plant nutrients in such kinds and proportions as required by crops during growth;
- the effective soil depth, available for root development and foothold of the plant;
- soil texture and stoniness, at the surface and within the whole depth of soil required for normal plant development;
- the absence of soil salinity and of specific toxic substances or iron deleterious to plant growth;
- other specific properties, e.g., soil tilth as required for germination and early growth.

b. External requirements: in addition to the above internal soil requirements of plants, a number of external soil requirements are of importance, e.g.:

- slope, topography and characteristics determined by micro- and macro relief of the land;
- occurrence of flooding as related to crop susceptibility to flooding during the growing period (e.g., potato, maize very susceptible), or inversely, to flooding requirements (e.g., rice). The incidence, regularity (irregularity) and depth of flooding are important factors determining the potential use of extensive river flood plain soils;
- soil accessibility and trafficability under certain management systems.

Table 3.2 CLIMATIC ADAPTABILITY ATTRIBUTES OF FORAGE LEGUMES AND SOWN PASTURES

Attributes	Verano Stylo	Chamaecrista	Centrosema	Siratro	Lablab	Forage vigna	Sown pasture
Species	Stylosanthes hamata	Chamaecrista rotundifolia	Centrosema pubescens	Macroptilium atropurpureum	Lablab purpureus	Vigna spp.	see footnote page 29
Photosynthesis pathway	C3	C3	C3	C3	C3	C3	C4
Crop adaptability group	II	II	II	II	II	II	III + IV
Length of growth cycle (days)	> 120	> 60	> 90	> 60	> 60	> 60	> 60
Harvested part	Foliage	Foliage	Foliage	Foliage	Foliage	Foliage	Foliage
Main product	Protein rich biomass	Protein rich biomass	Protein rich biomass	Protein rich biomass	Protein rich biomass	Protein rich biomass	Biomass
Growth habit	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Indeterminate	Determinate
Life span: Natural Cultivated	Perennial Annual	Perennial Annual	Perennial Annual	Perennial Annual	Annual Annual	Annual Annual	Annual/Peren. Annual/Peren.
Yield: Location Formation period	Foliage MA	Foliage MA	Foliage MA	Foliage MA	Foliage MA	Foliage MA	Foliage MA

MA - Most or all of growth cycle/period

From the basic soil requirements a number of response related soil characteristics can be derived for the forage species. One of these characteristics is for instance, soil pH. Optimal soil pH is known and can be quantified by a range within which it is not limiting to growth. Outside the optimal range, there is a critical range within which the forage species can be grown successfully but with diminished yield. Beyond the critical range, the forage species cannot be expected to yield satisfactorily unless special precautionary management measures are taken.

The same holds for other soil requirements related to soil characteristics. Many soil characteristics can be defined in a range that is optimal for a given 'crop', a range that is critical or marginal, and a range that is unsuitable under the present technology.

Table 3.3 presents optimal and critical ranges of forage legumes and sown pasture for the following soil characteristics: terrain slope, soil depth, soil drainage, flooding, texture and clay type, natural fertility (including cation exchange capacity, percent base saturation and organic matter), salinity, pH, free calcium carbonate content and gypsum content.

3.5 Agro-climatic Suitability

The agro-climatic suitability procedures aim at (a) evaluating the prevailing climatic conditions as constituting production resources and (b) assessing the likely effects of abiotic stresses (moisture, temperature), biotic stresses (pests and diseases) and workability constraints that operate through year-to-year variations in weather.

The agro-climatic suitability is achieved through a number of successive steps:

(i) matching temperature requirements to temperature conditions prevailing in each of the thermal zones, and determining which zones qualify for further consideration in the matching exercise;

(ii) computation of constraint-free consumable biomass yield potential by individual length of growing period zones;

(iii) matching to moisture conditions in each of the growing period zones, including assessing loss in yield potential due to moisture stress;

(iv) assessing loss in yield potential due to biotic stresses of pests, and diseases;

(v) assessing loss in yield potential due to excessive wetness constraints resulting from weather conditions;

(vi) combining the above assessment with agroclimatic suitability by applying the yield losses to potential yield and quantifying agronomically attainable yields.

Table 3.3 EDAPHIC ADAPTABILITY INVENTORY

CROPS	SLOPE (PERCENT)				DRAINAGE		FLOODING		TEXTURE			
	High inputs		Int./Low inputs		All inputs		All inputs		High inputs		Int./Low inputs	
	Optimum	Marginal	Optimum	Marginal	Optimum	Range	Optimum	Marginal	Optimum	Range	Optimum	Range
Verano stylo	0-8	8-16	0-8	8-24	W-MW	I-SE	F0	F1	L-SC	SL-KC	L-SC	L-KC
Chamaecrista	0-8	8-16	0-8	8-24	MW-SE	I-E	F0	F1	L-CL	LS-KC	L-CL	LS-KC
Centro	0-8	8-16	0-8	8-24	MW-W	I-SE	F0	F1	L-C	LS-MCs	L-SC	LS-KC
Siratro	0-8	8-16	0-8	8-24	MW-W	I-SE	F0	F1	L-C	LS-KC	L-SC	LS-KC
Lablab	0-8	8-16	0-8	8-20	W-SE	MW-E	F0	F1	L-SC	SL-KC	L-SC	LS-KC
Forage vigna	0-8	8-16	0-8	8-20	MW-W	I-SE	F0	F1	SL-SCL	LS-KC	SL-SCL	LS-KC
Sown grasses	0-8	8-16	0-8	8-20	MW-W	I-SE	F0	F1	SL-SCL	LS-KC	SL-SCL	LS-KC

CROP	DEPTH (cm)		CaCO3 (PERCENT)		GYPSUM (PERCENT)		pH		FERTILITY REQUIREMENTS	SALINITY (mmhos)	
	All inputs		All inputs		All inputs		All inputs		All inputs	All inputs	
	Optimum	Marginal	Optimum	Marginal	Optimum	Marginal	Optimum	Range	Range	Optimum	Range
Verano stylo	>40	20-40	0-25	15-25	0-3	3-15	5.5-7.5	5.0-8.2	low/moderate	0-3	3- 6
Chamaecrista	>50	25-50	0-25	25-50	0-3	3-15	5.5-7.5	5.2-8.2	low	0-4	4- 6
Centro	>50	25-50	0-30	30-75	0-5	5-20	5.5-8.2	5.2-8.5	low/moderate	0-5	5-10
Siratro	>50	25-50	0-15	15-30	0-3	3-15	5.5-7.5	5.2-8.2	low	0-2	2- 4
Lablab	>75	50-75	0-25	20-50	0-3	3-15	6.0-7.5	5.5-8.2	moderate	0-3	3- 6
Forage vigna	>75	50-75	0-20	20-35	0-3	3-15	5.2-7.5	5.0-8.2	low/moderate	0-3	3- 6
Sown grasses	>75	50-75	0-20	20-35	0-3	3-15	5.2-7.5	5.0-8.2	low/moderate	0-3	3- 6

<u>Drainage classes</u>

I = imperfectly drained
MW = moderately well drained
W = well drained
SE = somewhat excessively drained
E = excessively drained

<u>Flooding classes</u>

F0 = no floods
F1 = occasional floods
F2 = frequent floods

<u>Texture classes</u>

MCs = montmorrillonitic clay, structured
C = clay (mixed unspecified)
KC = kaolinitic clay
SC = sandy clay
CL = clay loam
SCL = sandy clay loam
L = loam
SL = sandy loam
LS = loamy sand

In the FAO/AEZ system, the assessment of constraints is achieved by semi-quantifying the constraints in terms of reduction ratings, according to the different constraints and their severity for each LUTs in each length of growing period zone and thermal zone.

Four suitability classes are employed to rate the requirements/ constraints. Where requirements are fully met and agroclimatically attainable yield is more than 80 percent of the maximum attainable yield, the zone is adjudged as 'very suitable' (VS). Where conditions are sub optimal and agro climatically attainable yield is in the range 40-80 percent of the maximum attainable yield, the zone is adjudged as 'suitable' (S). Where agroclimatically attainable yield is in the range 20-40 percent of the maximum attainable yield, the zone is adjudged as 'marginally suitable' (MS). Where requirements are not adequately met or not met at all, the zone is adjudged as 'not suitable' (NS).

3.5.1 Thermal Zone Suitability

The initial step in the agroclimatic matching process is comparison of the temperature requirements of the forage legumes and sown pastures with the temperature conditions of the identified thermal zones in West Africa. Table 3.4 presents for each of the thermal zones suitability ratings.

In this table a rating of S indicates that temperature conditions for photosynthesis and phenology are optimal and that it is possible to achieve the maximum yield potential. If there are no further climatic and edaphic limitations. A rating of N indicates that the zone is not suitable for production.

Table 3.4. THERMAL ZONES AND THEIR SUITABILITY RATINGS FOR VERANO STYLO, CHAMAECRISTA, CENTROSEMA, SIRATRO, LABLAB, FORAGE VIGNA AND SOWN PASTURE

Thermal Zone	Growing Period Temperature (^oC)	Suitability Ratings						
		Verano Stylo	Chamae -crista	Centro- sema	Siratro	Lablab	Forage Vigna	Sown Pasture
Warm Tropics	>20	S	S	S	S	S	S	S
Mod.Cool Tropics	15-20	N	N	N	N	N	N	S
Cool Tropics	5/10-15	N	N	N	N	N	N	N
Warm Subtropics (summer rainfall)	>20	S	S	S	S	S	S	S
Mod.Cool Subtropics (summer rainfall)	15-20	N	N	N	N	N	N	S
Cool Subtropics (summer rainfall)	5/10-15	N	N	N	N	N	N	N
Cool Subtropics (winter rainfall)	5/10-20	N	N	N	N	N	N	N

3.5.2 Potential Net Biomass and Yield

The methodology for the calculation of net biomass and constraint-free yields by suitable thermal zone is according to Kassam (1977), and is presented in this section.
Net biomass (Bn) is calculated from the equation:

$$Bn = (0.36\ bgm \times L) / (1/N + 0.25\ Ct) \quad (1)$$

where:

- bgm = maximum rate of gross biomass production at leaf area index (LAI) of 5.
- L = maximum growth ratio, equal to the ratio of bgm at actual LAI to bgm at LAI of 5. (L at LAI 1, 2, 3, 4 and 5 is 0.4, 0.6, 0.8, 0.9 and 1.0 respectively).
- N = length of crop growth cycle.
- Ct = maintenance respiration, dependent on both crop and temperature; given by the relation: $Ct = C30\ (0.0044 + 0.0019\ T + 0.0010\ T^2)$. At 30°C, C=0.0283 for a legume and C=0.0108 for a non-legume.

Constraint-free yield (By) is calculated from net biomass (Bn) from the equation:

$$By = Hi \times Bn \quad (2)$$

where:

- Hi = Harvest index i.e., proportion of the net biomass of the crop that is economically useful (i.e. consumable portion in the case of forage legumes and sown pasture)

The maximum rate of gross biomass production (bgm) is dependent on the maximum rate of CO_2 exchange (Pm). Pm values for the forage legumes and sown pasture are given in Table 3.5.

Table 3.5 MAXIMUM RATE OF PHOTOSYNTHESIS (Pm in kg ha^{-1} hr^{-1})

	Day-time Temperature °C							
	10	15	20	25	30	35	40	45
Verano Stylo	0	15	35	40	40	35	5	0
Chamaecrista	0	15	40	45	45	40	5	0
Centrosema	0	15	35	40	40	35	5	0
Lablab	0	15	40	55	55	40	5	0
Siratro	0	15	35	45	45	35	5	0
Forage Vigna	0	15	35	45	45	35	5	0
Sown Pasture	5	45	65	65	65	65	45	5

The actual rate of maximum gross biomass production (bgm), with Pm = 20 kg ha^{-1} hr^{-1} and LAI of 5 is calculated from the equation:

$$bgm = F \times bo + (1-F)\ bc \quad (3)$$

where:

- F = fraction of the daytime the sky is clouded, or $F = (Ac - 0.5\ Rg)/(0.8\ Ac)$ where Ac is the maximum active incoming short-wave radiation on clear days in cal cm-2 day^{-1} (Table 3.6) and Rg is the incoming short-wave radiation(cal cm^{-2} day^{-1})
- bo = gross dry matter production rate of a standard crop for a given location on a completely overcast day, kg ha^{-1} day^{-1} (Table 3.6)

bc = gross dry matter production rate of standard crop for a given location on a clear (cloudless) day, kg ha^{-1} day^{-1} (Table 3.6)

When Pm is greater than 20 kg ha^{-1} hr^{-1}, bgm is given by the equation:

$$bgm = F(0.8 + 0.01Pm)bo + (1 - F)(0.5 + 0.025Pm)bc \quad (4)$$

When Pm is less than 20 kg ha^{-1} hr^{-1}, bgm is given by the equation:

$$bgm = F(0.5 + 0.025Pm)bo + (1 - F)(0.05Pm)bc \quad (5)$$

For the study, crop characteristics that apply in the computation of net biomass and yield are:

(a) length of growth cycle;
(b) Leaf area index (LAI) at Maximum growth rate, and
(c) harvest index (Hi).

Lengths of growth cycles, leaf area indexes at maximum growth rate and harvest indexes (the portion of the biomass that is consumable by grazing animals) of the forage legumes and sown pasture considered in the net biomass and yield computation are given in Table 3.7.

An example of how to calculate net biomass and yield for a location (Kaduna, Nigeria) is given below.

Table 3.6 THE PHOTOSYNTHETICALLY ACTIVE RADIATION ON VERY CLEAR DAYS (Ac) IN CAL CM-2 DAY-1 AND THE DAILY GROSS PHOTOSYNTHESIS RATE OF CROP CANOPIES ON VERY CLEAR (bc) AND OVERCAST (bo) DAYS IN KG HA-1 DAY-1 FOR Pm = 20 kg CH2O KG HA-1 HR-1, (FROM DE WIT)

Latitude (N)		Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0°	Ac	343	360	369	364	349	337	342	357	368	365	349	337
	bc	413	424	429	426	417	410	413	422	429	427	418	410
	bo	219	226	230	228	221	216	218	225	230	228	222	216
10°	Ac	299	332	359	375	377	374	375	377	369	345	311	291
	bc	376	401	422	437	440	440	440	439	431	411	385	370
	bo	197	212	225	234	236	235	236	235	230	218	203	193
20°	Ac	29	293	337	375	394	400	399	386	357	313	264	238
	bc	334	371	407	439	460	468	465	451	425	387	348	325
	bo	170	193	215	235	246	250	249	242	226	203	178	164
30°	Ac	191	245	303	363	400	417	411	384	333	270	210	179
	bc	281	333	385	437	471	489	483	456	412	356	299	269
	bo	137	168	200	232	251	261	258	243	216	182	148	130

AN EXAMPLE CALCULATION OF POTENTIAL NET BIOMASS AND YIELD OF VERANO STYLO AT KADUNA, NIGERIA

Climate

Location : 10^{o} 36' N and 7^{o} 27' E
Altitude : 645 m
Growing period : 195 days
Start growing period : 1 May
End growing period : 15 November
Average radiation (Rg) : 411 cal cm^{-2} day
Average day-time temperature : 25.8 ^{o}C
Average 24hr mean temperature : 24.2 ^{o}C

Crop

Crop : Verano stylo
Growth cycle : 150 days
Leaf area index at maximum growth rate : 5
Harvest index : 0.55
Crop adaptability : Photosynthesis pathway C_3

Calculation of rate of gross biomass production (bgm)

- Photosynthesis rate Pm at 25.8 ^{o}C : 40 kg ha^{-1} hr^{-1} (Table 3.5)
  Difference in Pm relative to Pm = 20 kg ha^{-1} hr^{-1} : 100%
- Average photosynthetically active radiation on clear days (Ac) : 371 cal cm^{-2} day^{-1} (Table 3.6)
- Fraction of the day-time when the sky is overcast (F) : 0.56
  (from equation $F = (Ac - 0.5Rg)/0.8Ac$)
- Average rate of gross biomass production for perfectly clear days, at Pm = 20 kg ha^{-1} hr^{-1} (bc) : 435 kg ha^{-1} hr^{-1} (Table 3.6)
- Average rate of gross biomass production for totally overcast days, at Pm = 20 kg ha^{-1} hr^{-1} (bo) : 232 kg ha^{-1} hr^{-1} (Table 3.6)
- Rate of gross biomass production, at Pm = 20 kg ha^{-1} hr^{-1} at LAI of 5: 321 kg ha^{-1} day^{-1} (from equation 3)
- Rate of gross biomass production at Pm = 40 kg ha^{-1} hr^{-1}, at LAI of 5 (bgm): 443 kg ha^{-1} day^{-1} (from equations 3 and 4)

Calculation of total net biomass production (Bn) and Yield (By)

- Maintenance respiration coefficient at 30 ^{o}C : 0.0283 (for legume crop)
- Maintenance respiration coefficient at 24.4 (C_t) ^{o}C : 0.017
  (from equation $C_t = C_{30}\,(0.0044 + 0.0019\,T + 0.0010\,T^2)$)

Net biomass (Bn): 14.3 t/ha (equation 1)

Yield (By): 7.9 t/ha (equation 2)

Table 3.7 GROWTH CYCLE, LEAF AREA INDEX AND HARVEST INDEX BY LGP ZONE

		Growing period (days)										
		75- 89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Verano stylo	1st year growth cycle	15- 30	30- 60	60- 90	90-120	120-150	150-180	180-210	180-210	180-210	180-210	180-210
	LAI	0.25	0.45	1.5	2.5	4.0	5.0	5.0	5.0	5.0	5.0	5.0
	2nd/3rd year growth cycle	30- 60	60- 90	90-120	120-150	150-180	180-210	210-240	210-240	210-240	210-240	210-240
	LAI	0.45	1.5	2.5	4.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Harvest Index	0.6	0.6	0.6	0.6	0.65	0.7	0.7	0.7	0.7	0.7	0.7
Chamaecrista	1st year growth cycle	15- 30	30- 60	60- 90	90-120	120-150	150-180	180-210	180-210	180-210	180-210	180-210
	LAI	0.5	1.0	1.7	3.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	2nd/3rd year growth cycle	30- 60	60- 90	90-120	120-150	150-180	180-210	210-240	210-240	210-240	210-240	210-240
	LAI	1.0	1.7	3.5	5.0	5.0	5.0	5.0	5.0	5.0	5.0	5.0
	Harvest Index	0.6	0.6	0.6	0.6	0.65	0.7	0.7	0.7	0.7	0.7	0.7
Centrosema	1st year growth cycle	15- 30	30- 60	60- 90	90-120	120-150	150-180	180-210	180-210	180-210	180-210	180-210
	LAI	0.5	0.5	1.0	2.0	2.5	2.5	3.0	3.5	3.0	3.0	3.0
	2nd/3rd year growth cycle	30- 60	60- 90	90-120	120-150	150-180	180-210	210-240	210-240	210-240	210-240	210-240
	LAI	0.5	1.0	3.0	4.5	5.0	5.0	5.0	4.5	4.5	4.5	4.5
	Harvest Index	0.6	0.6	0.6	0.6	0.65	0.7	0.7	0.7	0.7	0.7	0.7
Siratro	1st year growth cycle	15- 30	30- 60	60- 90	90-120	120-150	150-180	180-210	180-210	180-210	180-210	180-210
	LAI	0.5	1.5	2.0	2.5	3.0	3.0	3.0	3.0	2.5	2.5	2.5
	2nd/3rd year growth cycle	30- 60	60- 90	90-120	120-150	150-180	180-210	210-240	210-240	210-240	210-240	210-240
	LAI	0.7	2.0	3.5	5.0	5.0	5.0	5.0	4.5	4.5	4.5	4.5
	Harvest Index	0.6	0.6	0.6	0.6	0.65	0.7	0.7	0.6	0.55	0.5	0.4
Lablab	1st year growth cycle	15- 25	25- 50	50- 75	75-125	125-150	125-150	125-150	125-150	125-150	125-150	180-210
	LAI	1.0	1.5	3.0	4.0	4.0	5.0	5.0	5.0	5.0	5.0	5.0
	2nd/3rd year growth cycle	30- 60	60- 90	90-120	120-150	150-175	150-175	150-175	150-175	150-175	150-175	150-175
	LAI	2.5	4.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Harvest Index	0.6	0.6	0.75	0.75	0.75	0.75	0.7	0.6	0.55	0.55	0.55
Forage vigna	1st year growth cycle	15- 45	45- 75	75-100	100-125	125-175	175-210	210-240	240-275	240-275	240-275	240-275
	LAI	1.0	2.0	3.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	2nd/3rd year growth cycle	15- 45	45- 75	75-100	100-125	125-175	175-210	210-240	240-275	240-275	240-275	240-275
	LAI	1.0	2.0	3.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0	6.0
	Harvest Index	0.35	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4	0.4
Sown Pastures	1st year growth cycle	15- 30	30- 60	60- 90	90-120	120-150	150-180	150-180	150-180	150-180	150-180	150-180
	LAI	0.5	0.7	2.0	3.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0
	2nd/3rd year growth cycle	15- 30	30- 60	60- 90	90-120	120-150	150-180	150-180	150-180	150-180	150-180	150-180
	LAI	0.5	0.7	2.0	3.0	5.0	6.0	6.0	6.0	6.0	6.0	6.0
	Harvest Index	0.5	0.5	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55	0.55

Constraint-free consumable net biomass potentials (for the forage legumes and sown grasses) for 1st, and 2nd and 3rd year are presented in Table 3.8.

For low input level conditions, the constraint-free consumable biomass for the forage legumes and sown pastures have been assumed as 25 percent of the constraint-free consumable biomass under high inputs.

This important assumption is based on empirical evidence (M.A. Mohamed-Saleem, unpublished) A yield difference of some 50 percent is attributed to low fertility status and no nutrient application. Sub-optimal timing of pasture management practices and maintenance of pasture quality is expected to result in an additional 50 percent of yield difference with high input conditions

Further it is assumed that yields at intermediate inputs level are positioned halfway between the constraint-free consumable biomass yield produced under low and high level input conditions.

3.5.3 Agro-climatic Constraints

The constraint-free biomass reflect potentials in respect of the effect of the prevailing temperature and radiation regimes on crop growth within the lengths of growing periods.

In the agro-climatic suitability assessment yield losses, likely to occur due to agro-climatic constraints, must be taken into account. Climatic constraints causing losses in yield and quality of produce of forage legumes and pasture are as follows:

(a) yield losses due to moisture deficit constraints;
(b) yield losses due to the effect of pests and diseases;
(c) yield losses due to excess moisture, i.e., workability and excess moisture stress constraints.

The above agro-climatic constraints are complex and dynamic and their interrelations make it difficult to assess quantitatively their effects.

The assessment of severity of above constraints by length of growing period zone for each of the six forage legumes and sown pasture are presented in Tables 3.9-3.15. Constraints are expressed as a percentage of constraint-free net biomass, moderate constraints are taken as 25 percent yield reduction, severe constraints as 50 percent.

The agroclimatic constraint tables are organized by level of inputs, high respectively low/intermediate. The moisture deficit stress refers to early season (ES), mid season (MS) and late season (LS) periods. Pest and diseases constraints are separately rated for the first, second and third year of the cycle. The excess moisture constraints cover workability and excess moisture stress separately.

In general for forage species, with increasing length of growing period and wetness, constraints due to diseases (e.g., anthracnose in verano stylo, leaf spot in centrosema and rhizoctonia mosaic in siratro), excess moisture stress (e.g., root asphyxiation in verano stylo and chameacrista and workability become severe (Boonman, 1993). With decreasing reference length of growing period and dryness, constraints due to moisture stress and to some extent insect pests become severe.

Table 3.8 **CONSTRAINT-FREE CONSUMABLE BIOMASS YIELD (t/ha)**

		Growing period (days)										
		75- 90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-365	365
Verano stylo	1st year growth cycle	0.1- 0.3	0.5- 1.0	2.4- 3.3	4.6- 5.6	7.8- 8.9	10.7-11.9	11.9-13.0	11.9-13.0	11.9-13.0	11.0-13.9	11.0-13.9
	2nd/3rd year growth cycle	0.5- 1.0	2.4- 3.3	4.6- 5.6	7.2- 8.3	10.0-11.1	12.0-13.0	13.0-13.9	13.0-13.9	13.0-13.9	13.0-13.9	13.0-13.9
Chamaecrista	1st year growth cycle	0.3- 0.4	0.8- 1.5	2.4- 3.2	5.0- 6.1	7.8- 9.0	9.7-10.8	9.7-10.8	9.7-10.8	9.7-10.8	9.7-10.8	9.7-10.8
	2nd/3rd year growth cycle	0.8- 1.5	2.4- 3.2	5.0- 6.1	7.2- 8.2	9.0-10.0	10.8-11.7	12.1-13.0	12.1-13.0	12.1-13.0	12.1-13.0	12.1-13.0
Centrosema	1st year growth cycle	0.2- 0.4	0.4- 0.7	1.3- 1.8	3.1- 3.8	4.8- 5.6	6.0- 6.8	8.1- 8.5	8.5- 9.1	9.1- 9.7	9.1- 9.7	9.1- 9.7
	2nd/3rd year growth cycle	0.4- 0.8	1.6- 2.1	4.7- 5.7	7.1- 8.1	9.0-10.1	10.8-11.7	11.7-12.5	12.5-13.2	12.5-13.2	12.5-13.2	12.5-13.2
Siratro	1st year growth cycle	0.2- 0.4	1.2- 2.2	2.6- 3.5	4.1- 5.0	6.2- 7.2	7.8- 8.6	8.6- 9.3	8.0- 8.5	7.8- 8.3	7.1- 7.5	5.7- 6.0
	2nd/3rd year growth cycle	0.8- 1.3	2.9- 3.8	5.4- 6.4	7.6- 8.6	9.4-10.3	11.1-12.0	12.0-12.5	10.7-11.3	9.8-10.3	8.9- 9.9	7.1- 7.5
Lablab	1st year growth cycle	0.5- 0.8	1.0- 1.7	3.9- 5.4	6.5- 8.0	8.0- 9.2	9.6-10.7	9.0-10.0	7.7- 8.6	7.0- 7.9	7.0- 7.9	7.0- 7.9
	2nd/3rd year growth cycle	1.8- 3.2	4.3- 5.9	8.0- 9.8	9.8-11.3	11.3-12.3	11.3-12.3	10.5-11.5	9.0- 9.8	8.3- 9.0	8.3- 9.0	8.3- 9.0
Forage vigna	1st year growth cycle	0.3- 0.7	1.4- 2.1	2.8- 3.4	4.2- 4.9	4.9- 6.4	6.4- 7.0	7.0- 7.8	7.5- 8.0	7.5- 8.0	7.5- 8.0	7.5- 8.0
	2nd/3rd year growth cycle	0.3- 0.7	1.4- 2.1	2.8- 3.4	4.2- 4.9	4.9- 6.4	6.4- 7.0	7.0- 7.8	7.5- 8.0	7.5- 8.0	7.5- 8.0	7.5- 8.0
Sown Pastures	1st year growth cycle	0.2- 0.5	0.6- 1.2	3.1- 4.4	5.9- 7.5	9.4-11.2	11.8-13.6	11.8-13.6	11.8-13.6	11.8-13.6	11.8-13.6	11.8-13.6
	2nd/3rd year growth cycle	0.2- 0.5	0.6- 1.2	3.1- 4.4	5.9- 7.5	9.4-11.2	11.8-13.6	11.8-13.6	11.8-13.6	11.8-13.6	11.8-13.6	11.8-13.6

Table 3.9 AGRO-CLIMATIC CONSTRAINTS FOR VERANO STYLO - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	50	50	25	25	25	25	-	-	-	-	-	-	-	-	-	72	72	72	72	72
90-120	25	25	25	25	-	-	-	-	-	-	-	-	-	-	-	58	58	58	58	58
120-150	25	25	25	25	-	-	-	-	-	-	-	-	-	-	-	44	44	44	44	44
150-180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	-	-	25	25	25	-	-	-	-	-	-	25	25	25
270-300	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
300-330	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
330-364	-	-	-	-	-	-	25	25	50	50	50	-	-	25	25	44	44	62	62	62
365	-	-	-	-	-	-	25	25	50	50	50	-	-	25	25	44	44	62	62	62

Table 3.10 AGRO-CLIMATIC CONSTRAINTS FOR CHAMAECRISTA - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	25	25	25	25	-	-	-	-	-	-	-	-	-	-	-	44	44	44	44	44
90-120	25	25	25	25	-	-	-	-	-	-	-	-	-	-	-	44	44	44	44	44
120-150	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
150-180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25	25	25
270-300	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25	25	25
300-330	-	-	-	-	-	-	-	-	-	-	-	-	-	50	50	50	50	50	50	50
330-364	-	-	-	-	-	-	-	-	-	-	-	-	-	50	50	50	50	50	50	50
365	-	-	-	-	-	-	-	-	-	-	-	-	-	50	50	50	50	50	50	50

L/I - Low and Intermediate levels of inputs

Table 3.11 AGRO-CLIMATIC CONSTRAINTS FOR CENTROSEMA - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	50	50	50	50	50	50	-	-	-	-	-	-	-	-	-	88	88	88	88	88
90-120	50	50	25	25	25	25	-	-	-	-	-	-	-	-	-	72	72	72	72	72
120-150	25	25	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25
150-180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
270-300	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
300-330	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
330-364	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
365	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44

Table 3.12 AGRO-CLIMATIC CONSTRAINTS FOR SIRATRO - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	50	50	50	50	25	25	25	25	25	25	25	-	-	-	-	86	86	86	86	86
90-120	50	50	25	25	-	-	-	-	-	-	-	-	-	-	-	62	62	62	62	62
120-150	25	25	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25
150-180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
270-300	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
300-330	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
330-364	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
365	-	-	-	-	-	-	50	50	50	50	50	-	-	50	50	75	75	75	75	75

L/I - Low and Intermediate levels of inputs

Table 3.13 AGRO-CLIMATIC CONSTRAINTS FOR LABLAB - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	50	50	50	50	25	25	25	25	25	25	25	-	-	-	-	79	79	79	79	79
90-120	25	25	25	25	25	25	25	25	25	25	25	-	-	-	-	68	68	68	68	68
120-150	25	25	25	25	25	25	-	-	25	25	25	-	-	-	-	58	58	68	68	68
150-180	25	25	-	-	-	-	-	-	25	25	25	-	-	-	-	25	25	44	44	44
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	25	25	25	25	50	-	-	25	25	44	44	44	44	62
270-300	-	-	-	-	-	-	25	25	25	25	50	-	-	25	25	44	44	44	44	62
300-330	-	-	-	-	-	-	25	25	25	25	50	-	-	25	25	44	44	44	44	62
330-364	-	-	-	-	-	-	25	25	25	25	50	-	-	50	50	63	63	63	63	75
365	-	-	-	-	-	-	25	25	50	50	50	-	-	50	50	63	63	75	75	75

Table 3.14 AGRO-CLIMATIC CONSTRAINTS FOR FORAGE VIGNA - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	50	50	50	50	50	50	25	25	25	25	25	-	-	-	-	91	91	91	91	91
90-120	50	50	25	25	-	-	25	25	25	25	25	-	-	-	-	72	72	72	72	72
120-150	25	25	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25
150-180	25	25	-	-	-	-	-	-	-	-	-	-	-	-	-	25	25	25	25	25
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
270-300	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
300-330	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
330-364	-	-	-	-	-	-	25	25	25	25	25	-	-	25	25	44	44	44	44	44
365	-	-	-	-	-	-	50	50	50	50	50	-	-	25	25	62	62	62	62	62

L/I - Low and Intermediate levels of inputs

Table 3.15 AGRO-CLIMATIC CONSTRAINTS FOR SOWN PASTURE - POTENTIAL YIELD LOSS (%)

LGP (days)	Moisture Deficit Stress Constraints						Pests & Diseases Constraints					Excess Moisture Constraints				Total Constraints				
	Early Season		Mid Season		Late Season		1st year		2nd year		3rd year	Workability		Stress		1st year		2nd year		3rd year
	High	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I	High	L/I	High	L/I	High	L/I	High	L/I	L/I
75-90	50	50	50	50	50	50	-	-	-	-	-	-	-	-	-	88	88	88	88	88
90-120	50	50	50	50	25	25	-	-	-	-	-	-	-	-	-	81	81	81	81	81
120-150	25	25	25	25	-	-	-	-	-	-	-	-	-	-	-	44	44	44	44	44
150-180	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
180-210	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
210-240	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
240-270	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
270-300	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
300-330	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
330-364	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25
365	-	-	-	-	-	-	25	25	25	25	25	-	-	-	-	25	25	25	25	25

L/I - Low and Intermediate levels of inputs

3.5.4 Agronomically Attainable Consumable Biomass Yield

Application of the appropriate reduction factors, according to the occurrence and severity of the agroclimatic constraints (Tables 3.9-3.15) to the constraint-free consumable biomass, given in Table 3.8 allows quantification of attainable consumable biomass. The annualized values for the forage species are presented in Table 3.16.

3.5.5 Agroclimatic Suitability

The results of the agroclimatic suitability assessment for the forage crops in terms of attainable consumable biomass in relation to length of growing period are presented in Figure 3.1. Similar results for cereals, root & tubers, food legumes and 'other crops' are presented in Figures 3.2, 3.3, 3.4 and 3.5 respectively. Annualized yields/consumable biomass of all forage and food crops considered in the present study are presented in Table 1 of Appendix 3.

An exception to the general methodology for agroclimatic suitability assessment applies to Fluvisols because the length of growing period does not fully reflect their particular circumstances with regards to moisture regime.

Cultivation of Fluvisols is generally governed by the depth, intensity and duration of flooding which occurs in the low-lying areas of these soils. These flooding attributes are generally controlled not by the amount of 'on site' rainfall but by external factors such as river flood regime, hydrological features of catchment area and catchment site relationship. Additionally, cultivation of these soils is normally confined to post flood periods, the crop being grown to a lesser or greater extent on moisture remaining in the soil. As a result of these factors, the anticipated consumable biomass according to length of growing period and the agroclimatic suitability are not applicable to Fluvisols.

Accordingly for forage legumes and sown pasture the following suitability rules have been applied to all areas of Fluvisols: All areas of all lengths of growing period zones greater than 240 days are agroclimatically classified as 'not suitable' because of excessive wetness/flooding and all areas of zero growing period zone are classified 'not suitable' because of aridity and salinity. In the remaining zones, 55% of all areas are classified as 'suitable'.

3.6 Agro-edaphic Suitability

The agroedaphic suitability classification is based on:

(i) a comparison of the soil requirements of crops with the edaphic conditions of soil unit described in the soil inventory, at three levels of inputs; and

(ii) modification of the soil unit evaluation by limitation imposed by texture, phase and slope conditions.

Table 3.16 ANNUAL CLIMATICALLY ATTAINABLE CONSUMABLE BIOMASS YIELD (t/ha)

		Maximum	Growing period (days) 75- 90	90-120	120-150	150-180	180-210	210-240	240-270	270-300	300-330	330-365	365
Verano stylo	High Inputs	11.9	0.1	0.8	2.2	6.4	9.5	11.9	11.1	9.5	7.2	6.0	6.0
	Intermediate Inputs	7.5	0.1	0.6	1.5	4.3	6.1	7.5	6.8	6.1	4.6	3.6	3.6
	Low inputs	3.0	0.0	0.2	0.6	1.7	2.5	3.0	2.8	2.5	1.6	1.6	1.6
Chamaecrista	High Inputs	10.7	0.4	1.1	4.2	6.7	8.9	10.7	8.1	8.1	5.7	5.7	5.7
	Intermediate Inputs	6.8	0.3	0.8	2.9	4.4	5.7	6.8	5.5	5.5	3.6	3.6	3.6
	Low inputs	3.0	0.1	0.3	1.2	1.8	2.3	2.7	2.2	2.2	1.5	1.5	1.5
Centrosema	High Inputs	8.8	0.1	0.4	2.6	5.0	7.4	8.8	7.7	8.1	6.2	6.2	6.2
	Intermediate Inputs	6.0	0.0	0.3	1.9	3.9	5.1	6.0	5.4	5.4	4.0	4.0	4.0
	Low inputs	3.0	0.0	0.1	0.8	1.6	2.0	2.4	2.2	2.2	1.6	1.6	1.6
Siratro	High Inputs	9.9	0.1	1.0	3.4	6.4	8.3	9.9	9.5	7.2	5.1	4.7	1.9
	Intermediate Inputs	6.8	0.1	0.7	2.3	4.4	5.5	6.5	5.2	4.7	3.3	3.0	1.1
	Low inputs	3.0	0.0	0.3	0.9	1.8	2.2	2.6	2.1	1.9	1.3	1.2	0.4
Lablab	High Inputs	11.0	0.3	1.0	2.2	5.7	10.2	11.0	5.7	4.9	4.5	2.7	2.2
	Intermediate Inputs	7.0	0.3	0.8	1.6	3.6	6.7	7.0	3.2	3.1	2.6	1.7	1.5
	Low inputs	2.8	0.1	0.3	0.6	1.4	2.7	2.8	1.3	1.1	1.0	0.7	0.6
Forage vigna	High Inputs	6.7	0.1	0.5	2.3	3.4	5.6	6.7	5.8	5.8	4.3	4.3	2.9
	Intermediate Inputs	4.2	0.0	0.3	1.5	2.1	3.5	4.2	3.6	3.6	2.7	2.7	1.8
	Low inputs	1.7	0.0	0.1	0.6	0.9	1.4	1.7	1.4	1.5	1.1	1.1	0.7
Sown pasture	High Inputs	12.6	0.0	0.2	2.1	6.7	10.3	12.7	12.7	12.7	12.7	9.5	9.5
	Intermediate Inputs	6.8	0.0	0.1	1.3	4.2	6.5	7.9	7.9	7.9	7.9	6.0	6.0
	Low inputs	3.0	0.0	0.0	0.5	1.7	2.6	3.2	3.2	3.2	3.2	2.4	2.4

Figure 3.1: AGRO-CLIMATICALLY ATTAINABLE YIELDS AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY OF FORAGE LEGUMES AND SOWN PASTURE

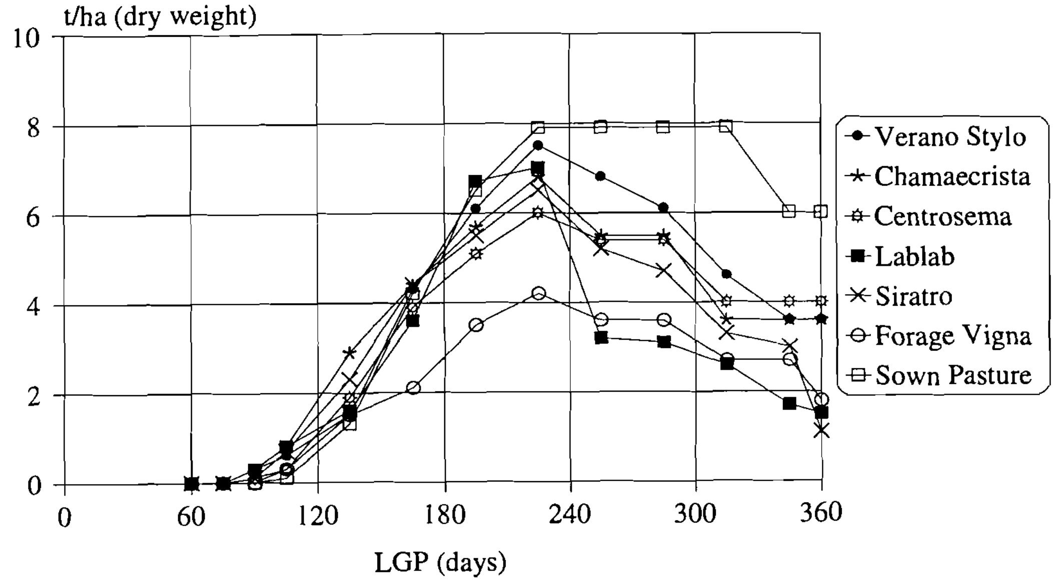


Figure 3.2: AGRO-CLIMATICALLY ATTAINABLE YIELDS AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY OF CEREALS

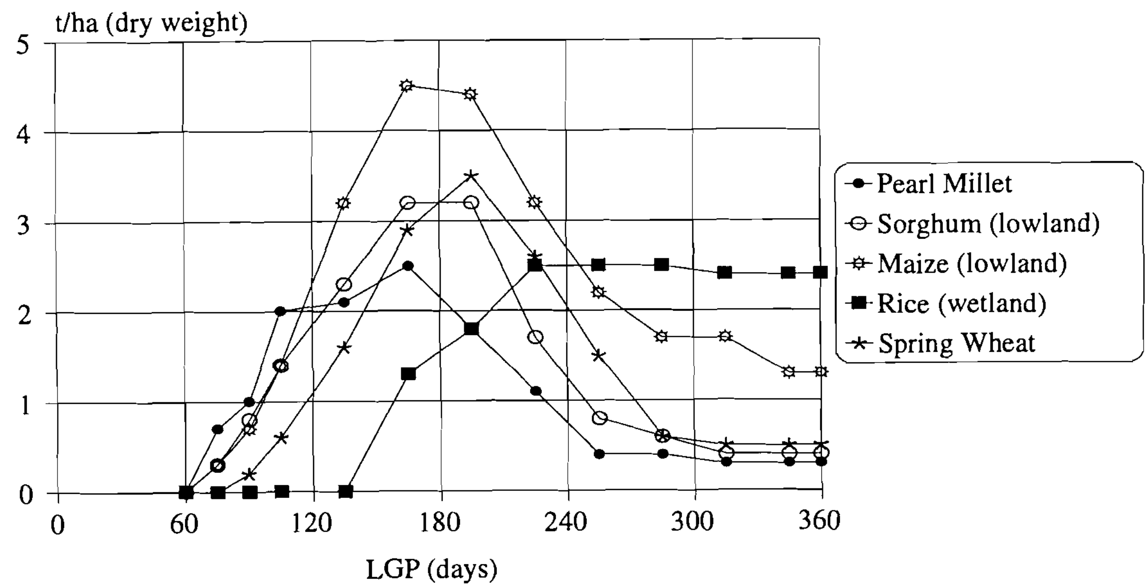


Figure 3.3: **AGRO-CLIMATICALLY ATTAINABLE YIELDS AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY OF LEGUMES**

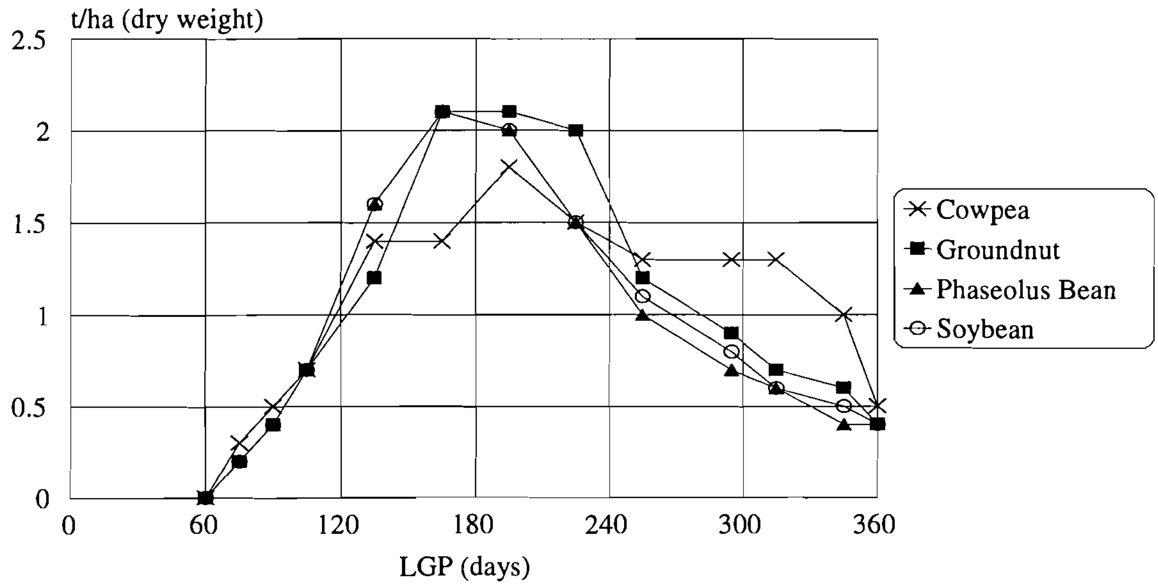


Figure 3.4: **AGRO-CLIMATICALLY ATTAINABLE YIELDS AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY OF ROOTS & TUBERS**

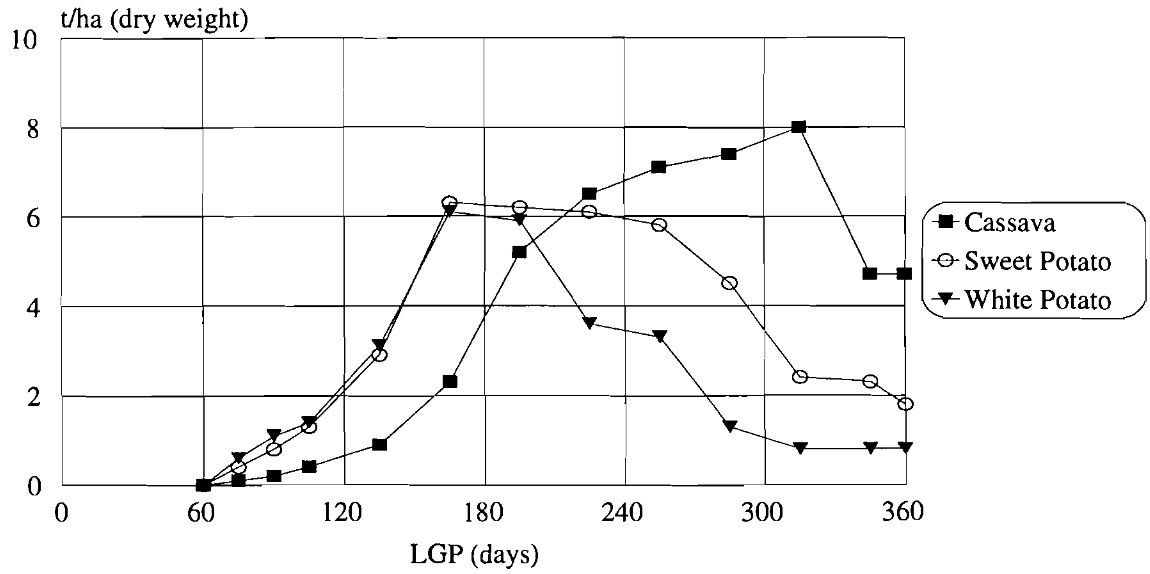
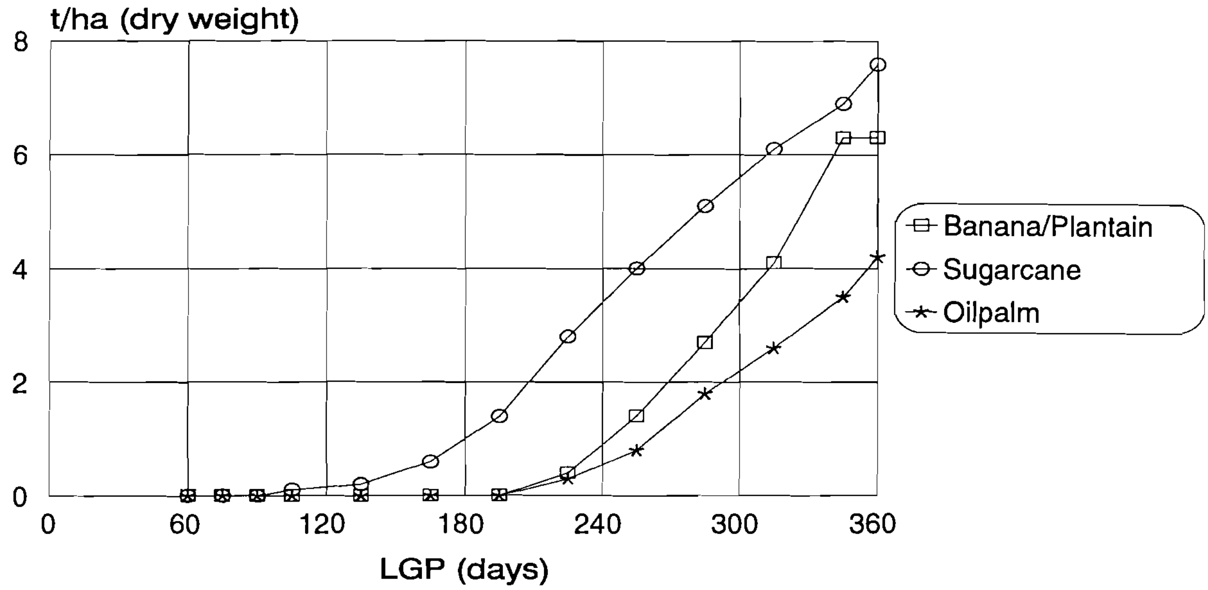


Figure 3.5: **AGRO-CLIMATICALLY ATTAINABLE YIELDS AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY OF PERENNIALS**



3.6.1 <u>Soil Unit Evaluation</u>

The soil unit evaluation is expressed in terms of ratings based on how far the edaphic conditions of a soil unit meet crop requirements under the specified level of inputs. The appraisal was effected in three basic classes, i.e., very suitable or suitable (S1), marginally suitable (S2), and not suitable (N). A rating of S1 indicates that there are no or only minor limitations to production, provided climatic conditions are suitable. The rating of S2 was given when it was considered that soil limitations are such that they would markedly affect production, yet not to the extent of making the land unsuitable. A rating of N was given when the soil limitations appear to be so severe that production is not suitable or, at best, very limited. The N rating is divided into N1 and N2, N1 referring to soil limitations that are considered ameliorable through major land improvements (including initial heavy fertilizer applications), and N2 where limitations are considered to be of a permanent nature. The ratings of all soil units for the three levels of inputs for the forage legumes and sown pasture are presented in Table 2 of Appendix 3.

The ratings are made on the assumption that there have been no major land improvements, The ratings take into account the actual quantitative definitions of the soil unit in making the assessment

Where combination ratings, e.g. S1/S2, are given for a soil unit it is considered that half the area occupied should be of one rating and the remaining half of the other and S1/S2/N2, 33 percent of the area for each of the ratings.

3.6.2 Texture Modifications

All ratings of soils with '1' textures (coarse) are decreased by one class, except units Qc, Ql, Qf, Qa, Tv, Po, Pl, Pf, Ph, Pp, Pg, P and Fx which remain unchanged because light texture limitations have already been applied in the soil unit ratings.

All ratings of soils with '2' (medium) and '3' (fine) textures remain unchanged, no modification being necessary as limitations imposed by heavy textures have been dealt with in the soil unit ratings.

3.6.3 Phase Modifications

Modifications were applied to the soil unit ratings, to take into account limitations imposed by phase conditions.

Phases, which by definition, indicate the presence of an indurated or cemented layer within 100 cm from the surface, were given combination ratings (e.g. S2/N2) assuming that in 50 percent of the area the layer is moderately deep (say 60-100 cm) and in the other half, the layer is shallow (less than 60 cm deep). In general, such depth limitations are less severe for forage crops than food crops. Shallow depths are also considered a more severe limitation to cultivation under high inputs, involving mechanization, especially for the Petro-phases which indicate a cemented layer. This assumption is applicable to the following phases: Petric, Petrocalcic, Petrogypsic, Petroferric, Fragipan and Duripan. The phase ratings for the forage species are given in Table 3 of Appendix 3.

3.6.4 Slope Modifications

Modifications to the soil unit ratings are made according to the six slope classes. Table 3.17 presents the slope ratings for forage legumes and sown pastures for three level of inputs.

Table 3.17 SLOPE RATINGS FOR FORAGE LEGUMES AND PASTURE

Slope Gradient Classes	Forage Legumes			Pastures		
	High	Int.	Low	High	Int.	Low
0-2%	S1	S1	S1	S1	S1	S1
2-8%	S1	S1	S1	S1	S1	S1
8-16%	S2	S2	S2	S1	S1	S1
16-30%	S2/N2	S2	S2	S2/N2	S2	S2
30-45%	N2	S2/N2	S2/N2	N2	S2/N2	S2/N2
>45%	N2	N2	N2	N2	N2	N2

3.7 Land Suitability

The agroclimatic suitabilities and the agroedaphic suitabilities are combined to arrive at land suitabilities. The procedures take account of all the inventoried attributes of the agro-ecological cell and compares them with forage species requirements, to give an easily understood picture of the suitability of land.

The four suitability classes are each linked to attainable consumable biomass for the three levels of inputs considered.

In essence, the land suitability classification has been computed by modifying the computed extents of lands in the four agro-climatic suitability classes by the ratings of the various soils inventoried, i.e., knowing the area of each growing period zone, its agroclimatic suitability, and the extent and degree of soil limitation to production, it is possible to compute the areas of land variously suited at the three levels of inputs considered.

The four classes of land suitabilities are related to attainable yield as a percentage of the maximum attainable yield under optimum agroclimatic and agroedaphic conditions, and so provide the necessary data for calculation of the rainfed production potential of any given area of West Africa.

Figure 3.6 illustrates schematically the procedures of the land suitability assessment.

Summaries of extents of land variously suited to rainfed cultivation of the forage legumes and sown grasses under high, intermediate and low level inputs for the 17 countries of West Africa are presented in Tables 4.1 - 4.7 of Appendix 3. Aggregation of land suitability assessments results from AEZ cell to GIS raster points has produced suitability results in map form. An example for land suitability of verano stylo at intermediate level of inputs is presented in Figure 3.7.

productivity in case forage legumes are assumed to be included in the cropping patterns[1].

Results of the sustainable land productivity assessment in terms of food crop and fodder productivity for three levels of input circumstances, at four levels of aggregation (i.e. agro-ecological cell, sub-national, national and regional levels) are discussed in section 4.5.

The agro-ecological cell level results are carried forward to the 'Spatial Optimal Use Resource Model' (SORUM) for the assessment of implications of improved primary productivity for crop-livestock systems, and for meeting future (year 2010 and 2025) national and regional demands (Volume 2 of this Report).

4.2 Multiple Cropping with Forage Legumes

Incorporation of forage legumes into traditional cropping patterns is another dimension for land-use intensification in terms of time and space. The objective here is to maximize economically attainable levels of crop production for human consumption and fodder for livestock from the same land unit. Conventionally production per unit intercropped area is the sum of crop yields from all crop components, and the intercropping advantage depicted by LER values greater than 1.0 is the ratio of land areas needed under sole cropping to intercropping to attain similar yield levels.

In the case of forage/crop mixtures however, there is only a single food crop component and livestock feed, derived as crop residue and herbage from the forage legume assumes equal economic importance from this system of production. Possibilities for improving feed production will be of most significance in areas where land is in short supply. Hence yield advantage per unit area of crop and forage mixtures needs to be judged from the viewpoint of their potential contributions to feed production by every component in the mixture, provided food crop yield per mixed cropped area is not significantly different to its sole crop yields from a similar land area.

Forage legumes in a crop mixture can be established and harvested at varying spacing and time in relation to the associated food crop(s). Where soil moisture is adequate for vegetative growth, forage legumes could be grown in association with food crops to increase the overall fodder quality. Even in areas considered unsuitable for growing food crops in mixtures (e.g. LGP 90-120 days), forages are amenable to grow in association with food crops. To reflect the flexibility of forage legumes to associate with food crops also in relatively drier areas, the LER ratings suggested by Kassam (1980) for multiple cropping is reviewed for the purpose of assessing forage legumes in mixed cropping systems. Table 4.1 reproduces LER values for crop mixtures and Table 4.2 present suggestions for LER ratings for crop/forage legume mixtures.

Table 1.1 of Appendix 4 presents agro-climatic productivity values of the food crops, forage legumes and natural and sown pastures considered in the present study. The values presented in Table 1 include intercropping and sequential cropping effects where applicable. For the food crops and natural pastures the values are taken from the study 'Land Resources for Populations of the Future' (FAO 1980).

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1 effects on soil erodibility have been accounted for in the model.

Table 4.1 **SUGGESTED LAND EQUIVALENT RATIOS (LER) AT DIFFERENT LEVELS OF INPUTS BY LENGTH OF GROWING PERIOD (LGP) AND CROP YIELD RELATIVE TO MAXIMUM ATTAINABLE YIELD FOR CROP MIXTURES (KASSAM 1980)**

LGP (days)	Inputs/Suitability							
	Low				Intermediate			
	NS	MS	S	VS	NS	MS	S	VS
< 120	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
120-270	1.0	1.1	1.2	1.3	1.0	1.05	1.1	1.15
> 270	1.0	1.2	1.3	1.4	1.0	1.1	1.15	1.2

Table 4.2 **SUGGESTED LAND EQUIVALENT RATIOS (LER) AT DIFFERENT LEVELS OF INPUTS BY LENGTH OF GROWING PERIOD (LGP) AND CROP YIELD RELATIVE TO MAXIMUM ATTAINABLE YIELD FOR CROP FORAGE LEGUME MIXTURES**

LGP (days)	Inputs/Suitability							
	Low				Intermediate			
	NS	MS	S	VS	NS	MS	S	VS
<90	1.0	1.0	1.0	1.0	1.0	1.0	1.0	1.0
90-120	1.0	1.1	1.1	1.1	1.0	1.1	1.1	1.1
120-270	1.0	1.2	1.3	1.4	1.0	1.2	1.3	1.4
> 270	1.0	1.2	1.3	1.5	1.0	1.2	1.3	1.5

Notes:

(1) Assessment takes into account additional DM production and quality per land area derived from forage legume.

(2) Under high level of inputs forage legumes and crops are assumed as specialized enterprises, and therefore mixtures of forage legumes and food crops are not considered as realistic options.

(3) As forage legumes require adequate Phosphorus for establishment a minimum supply of 15-20 kg of P is assumed even at low inputs level.

4.3 Fallow Land Requirements

In their natural state, many tropical soils cannot be continuously cultivated without undergoing degradation. Such degradation is marked by a decrease in crop yields and a deterioration in soil structure, nutrient status and other physical, chemical and biological attributes.

Under traditional farming systems, this deterioration is kept in check by alternating some years of cultivation with periods of fallow. The intensity of the necessary fallow is dependent on level of inputs, soil and climate conditions and crops. However the prime reason for incorporating fallows into crop rotations is to enhance sustainability of production through maintenance of soil fertility.

4.3.1 Natural Bush/Grass Fallow Land Requirements

Maintenance of nutrient fertility of land, cultivated with subsistence low inputs LUTs, is generally been achieved through natural bush or grass fallow as a means of soil fertility regeneration.

The natural bush or grass fallow requirements have been derived for the inventoried environmental conditions for four main groups of crops: cereals, legumes, roots and tubers, and banana and sugarcane (FAO/IIASA 1991). The environmental frame used consists of individual soil units, thermal zones, represented by warm (Tmean > 20^{o}C), moderately cool (Tmean 15-20^{o}C) and cool temperature regimes (Tmean 5-15^{o}C), and moisture regime, represented by length of growing period zones < 90, 90-120, 120-180, 180-270 and > 270 days.

Part A of Table 4.4 presents reference fallow requirements (F) as function of soil fertility. This factor is expressed as percentage of time during the fallow-cropping cycle (i.e. tf/(tc+tf)x100) the land must be put under fallow. The reference values have been used as basis for the scoring of natural bush/grass fallow requirements for a particular soil unit and crop group at low level inputs. For Fluvisols and Gleysols fallow factors are lower because of their special moisture and fertility conditions.

At the intermediate level of inputs the fallow requirements are taken as one third of those at the low level. At the high level of inputs, fallow requirements are set at 10%.

4.3.2 Forage Legume Fallows

Forage legumes provide a faster means for soil regeneration compared to natural bush/grass fallows (Hague and Jutzi, 1984; Reeves and Ewing, 1993; Mohamed-Saleem and Fischer, 1993). Sown forage legume fallows can provide a head start to the time required for natural bush/grass fallows to establish. This offers better early protection to the soil from torrential rains at the start of the rainy season. Also the forage legumes provide nitrogen accrual in the soil through biological fixation which in turn is enhancing the quality of livestock feed.

Forage legumes in a crop/livestock production system can be used in different ways. The following assumptions have been made to enable assessment of forage legumes in fallows:

(i) Uninterrupted forage growth from the time of sowing until strategically grazed in situ.

(ii) Forage legume fallow benefits are similar for those of natural bush/grass fallows with the exception in the case of forage legumes fallow where there is extra impact on soil fertility through increased organic matter and nitrogen resulting from additional biomass production and biological nitrogen fixation.

(iii) Capture of the accrued soil nitrogen by crops from the forage legumes is the main objective of forage legume fallow and other benefits are adjunct to nitrogen build up.

Soil nitrogen accrual potentials for the different legumes under West African conditions and available amount of legume-nitrogen in soil, available to crops after two years of forage legume fallow, estimated through bioassay are summarized in Table 4.3.

Table 4.3 NITROGEN ACCRUALS FOR FORAGE LEGUMES

Legume Group	Legume Type	Range N (kg/ha/yr)	Average N (kg/ha/yr)	Available N to crops after 2 years of Forage Legume Fallow	Available N to crops per year of Forage Legume Fallow
I	Chamaecrista	120-180	150	108	54
	Lablab	110-200	155	118	59
	Forage Vigna	130-170	150	120	60
II	Centrosema	150-250	200	136	68
	Siratro	170-200	185	122	61
	Verano Stylo	190-260	225	158	76

Based on nitrogen fixing and transferring abilities, chamaecrista, lablab and forage vigna (group I) could benefit crops up to an average of 58 kg/ha/year and centrosema, siratro and stylo (group II) under similar management situation benefit crops up to an average of 68 kg/ha/year.

Forage legume density in the fallow and biological nitrogen accruals vary depending on the soil fertility status. Inherently fertile soils with higher nitrogen levels suppress biological nitrogen fixation and nitrophilous grasses out compete forage legume establishment. Forage legumes also poorly establish in very infertile soils. Forage legume dominance is attained in moderately fertile and infertile to moderately infertile soils.

Ability of forage legumes in fallow to compensate soil nitrogen loss during the preceding crop cultivation phase is a function of the relative amounts of nitrogen accrued during the fallow phase. The frequency of cropping or the fallow factor (F) involving forage legume fallow or natural bush/grass fallow rotations will therefore depend on the relative gain in soil nitrogen during the respective fallows and is estimated as:

$$F_{\text{(legume fallow)}} = \frac{(a-b)}{(a-c)} * F_{\text{(natural bush/grass fallow)}} \quad (4.1)$$

where:

a = Soil nitrogen deficit during cultivation
b = Soil nitrogen gain during legume fallow
c = Soil nitrogen gain during natural fallow
$F_{\text{(natural bush/grass fallow)}}$ has been taken from FAO/IIASA (1991)

Part B and C of Table 4.4 present respectively reference fallow requirements as a function of soil fertility for Group I forage legumes (chamaecrista, lablab and forage vigna) and for Group II forage legumes (verano stylo, centrosema and siratro). Similar to the values presented in Part A of Table 4.4, these reference values are used for scoring of fallow requirements for a particular soil unit at low level inputs.

Table 4.4 REFERENCE FALLOW REQUIREMENTS AS FUNCTION OF SOIL FERTILITY

A. Natural Bush/Grass Fallow Requirements

Soil Fertility Capability	Warm					Moderately Cool					Cool				
	75-90	90-120	120-180	180-270	270-365	75-90	90-120	120-180	180-270	270-365	75-90	90-120	120-180	180-270	270-365
I	75	70	65	65	75	70	65	60	60	70	75	70	65	65	75
II	80	75	70	70	80	75	70	65	65	75	80	75	70	70	80
III	85	80	75	75	85	80	75	70	70	80	85	80	75	75	85
IV	90	85	80	80	90	85	80	75	75	85	90	85	80	80	90
Fluvisols	30	30	30	30	30	30	30	30	30	30	30	30	30	30	30
Gleysols	40	40	40	40	40	40	40	40	40	40	40	40	40	40	40

B. Forage Legumes Fallow Requirements (Group I: chameacrista, lablab, forage vigna)

Soil Fertility Capability	Warm					Moderately Cool					Cool				
	75-90	90-120	120-180	180-270	270-365	75-90	90-120	120-180	180-270	270-365	75-90	90-120	120-180	180-270	270-365
I	72	67	63	63	72										
II	72	68	63	63	72	Not applicable					Not applicable				
III	75	71	66	66	75										
IV	87	82	77	77	87										
Fluvisols	28	28	28	28	28	Not applicable					Not applicable				
Gleysols	38	38	38	38	38										

C. Forage Legumes Fallows Requirements (Group II: verano stylo, centrosema, siratro)

Soil Fertility Capability	Warm					Moderately Cool					Cool				
	75-90	90-120	120-180	180-270	270-365	75-90	90-120	120-180	180-270	270-365	75-90	90-120	120-180	180-270	270-365
I	69	65	60	60	69										
II	67	63	57	57	67	Not applicable					Not applicable				
III	68	64	60	60	68										
IV	84	80	75	75	84										
Fluvisols	27	27	27	27	27	Not applicable					Not applicable				
Gleysols	37	37	37	37	37										

FCC class:

- I Fertile soils
- II Moderately fertile soils
- III Infertile to moderately fertile soils
- IV Infertile soils

4.4 Soil Erosion - Productivity Loss

This section describes the soil erosion and productivity submodel, which quantifies implications of alternative land uses in terms of topsoil loss due to erosion and its impact on the productivity of land under different assumed soil conservation measures. The submodel is adapted from an existing model (FAO/IIASA 1991).

The methodology for the estimation of topsoil loss is essentially based on a modified Universal Soil Loss Equation (USLE): Wischmeier and Smith (1978). The topsoil loss is subsequently converted into productivity loss with or without specific soil conservation measures.

The Universal Soil Loss Equation (USLE) equates soil loss per unit area with the erosive power of rain, the amount and velocity of runoff water, the erodibility of the soil, and mitigating factors due to vegetation cover, cultivation methods and soil conservation. The USLE equation has been modified by separating the two elements of the cover and management factor C. The modified soil loss equation becomes as follows:

$$A = R \times K \times LS \times (C^* \times M) \times P. \qquad (4.2)$$

where:

A: Annual soil loss in t/ha
R: The rainfall erosion factor.
K: The soil erodibility factor.
LS: A combined factor to account for the length and steepness of the slope.
C*: The vegetation cover factor.
M: The management factor.
P: The physical protection factor.

The R factor has been modified to suit West African conditions (FAO 1977) and has been estimated from the following equation:

$$R = 5.44 \sum_{1}^{12} \frac{p2}{P} - 416 \qquad (4.3)$$

where:

p: monthly rainfall
P: annual rainfall

The other factors are adapted from FAO/IIASA 1991.

Equation 4.2 is used in the model to estimate topsoil loss under specified vegetation/crop cover and management conditions for each land utilization type (LUT) for each agro-ecological cell. This estimates in turn are related to productivity losses and conservation needs.
In the model, permissible slopes for various land uses under different levels of inputs circumstances have been defined as model variables, and these are given in Table 4.5. The critical slope values in the slope cultivation association screen define the upper slope limits to cultivation.

Table 4.5 **SLOPE-CULTIVATION ASSOCIATION SCREEN**

Land Utilization Type	Level of Inputs and Technology		
	Low	Intermediate	High
Dryland crops and forage legumes without soil conservation measures	< 30%	< 30%	< 16%
Dryland crops and forage legumes with soil conservation measures	< 30%	< 30%	< 30%
Wetland crops without soil conservation measures	, < 5%	< 5%	< 2%
Wetland crops with soil conservation measures*	< 30%	< 30%	< 30%
Coffee, Tea, forest and pasture with and without soil conservation measures	< 45%	< 45%	< 45%

* For wetland crops, terracing is required

Further, the model takes into account the loss in crop production by soil erosion through:

(a) the loss of topsoil which, in many soils, is the source of most or all the nutrient fertility; and

(b) reducing the overall depth of the soil profile so that eventually the soil water holding capacity and foothold capacity are reduced to a point where it limits yields.

A tolerable rate of soil erosion is considered to be one that over a specified number of years (e.g. 25, 50 or 100):

(a) does not result in a crop yield reduction of more than a specified amount due to loss of topsoil; and

(b) does not result in more than a specified proportion of land being downgraded to a lower class of agricultural suitability due to soil depth reduction.

These two criteria are not interdependent, so that tolerable rate of soil loss is taken as the lower of the two alternatives. The model therefore provides a framework for assessing tolerable soil loss, based on its likely impact on crop yields and the future availability of cultivable land.

The soil units of Soil Map of the World have been classified according to their susceptibility to productivity loss with loss of topsoil, and on the presence of other unfavourable subsoil conditions (Table 4.7). These rankings of susceptibility of the soils are related to actual yield losses, by inputs level, through a set of linear equations given in Table 4.8. The reduced impact of topsoil loss under intermediate and high levels of inputs is due to the compensating effect of fertilizers at their normal rates of use. It is assumed that the benefit of fertilizers is less on the more susceptible soils because of their more unfavourable subsoil conditions. Further, low rates of soil erosion are to some extent compensated by the formation of topsoil. The rate of topsoil formation can vary from <0.25 mm/year in dry and cold environments to >1.5 mm/year in humid and warm environments (Hammer 1981, Hudson 1981). The assessment of this topsoil regeneration capacity is included in the model (FAO/IIASA 1991).

Table 4.6 RANKING OF SOILS UNITS (SMW) ACCORDING TO THEIR SUSCEPTIBILITY TO PRODUCTIVITY LOSS PER UNIT OF TOPSOIL

Least susceptible	Intermediate susceptible	Most susceptible
Gleysols Vitric Andosols Vertisols Chernozems Vertic Cambisols Luvisols Histosols Fluvisols	Dystric Regosols Lithosols Rankers Rendzina Yermosols Xerosols Kastanozems Phaeozems Greyzems Cambisols except Vertic Cambisols Podzoluvisols Dystric Planosols Ferric Acrisols Nitosols Ferralsols	Regosols except Dystric Regosol Arenosols Andosols except Vitric Andosols Solonchaks Solonetz Podzols Planosols except Dystric Planosols Acrisols except Ferric Acrisols

Table 4.7 RELATIONSHIPS BETWEEN TOPSOIL LOSS AND YIELD LOSS

Soil Susceptibility ranking	Levels of Inputs and Technology	Equation
Least susceptible	Low	Y = 1.0 X
	Intermediate	Y = 0.6 X
	High	Y = 0.2 X
Intermediate susceptible	Low	Y = 2.0 X
	Intermediate	Y = 1.2 X
	High	Y = 0.4 X
Most susceptible	Low	Y = 7.0 X
	Intermediate	Y = 5.0 X
	High	Y = 3.0 X

Y = productivity loss in percent; X = topsoil loss in cm.

In the application of the soil erosion model, potential erosion losses for each LUT (foodcrops, forage legumes, grasses) are first assessed with the assumption that no specific soil conservation measures are applied, i.e. protection factor P = 1. When the topsoil loss is within the established tolerable limits, the associated productivity loss is estimated and applied to the productivity of the LUT/AEZ cell combination , if not, the productivity of the LUT/AEZ cell combination is considered not sustainable and therefore considered as not productive.

For the assessment with soil conservation, at each of the three levels of inputs relevant soil conservation measures have been selected. For low level inputs; ridge cultivation and trash lines, for intermediate inputs; tied ridging, trash lines and converse terraces and for high inputs converse terraces and bench terraces.

The effects of the selected conservation measures/practices on soil erosion (protection factor), are related to differences in climate, soil, topography and LUT, and have been quantified through relationships suggested by Mitchell (1986). The estimated protection factors are then applied in the topsoil loss and associated productivity loss assessments as described above.

Productivity estimates for each LUT/AEZ cell combination with and without various soil conservation options are stored and retained in the land productivity database.

4.4.1 Effect of Forage Legumes on Soil Erosion

Forage legumes influence soil erosion in two ways (a) through the specific soil cover (C* factor), and (b) through stabilizing effects on soil erodibility (K factor).

The canopy characteristics and random in field arrangement of forage legumes (similar to sown pasture) provides at equal ground cover an distinct advantage over annual crops. This may be demonstrated in Table 4.10 (Mitchell 1986). Further the cover development of forage legumes is faster than most annual crops, however slower than C4 grasses. Particular important is the relative fast establishment of protective ground cover of sown forage legumes fallows compared to natural fallows.

Table 4.8 COVER FACTOR (C*) FOR ANNUAL CROPS AND PASTURE/ FORAGE LEGUMES

Ground Cover (%)	0	10	20	30	40	50	60	70	80	90	100
Annual crops	1.0	1.0	1.0	1.0	0.86	0.72	0.58	0.44	0.30	0.16	0.02
Forage legumes and pastures	1.0	0.33	0.20	0.15	0.10	0.07	0.04	0.02	0.01	0.01	0.00

Forage legumes enhance soil characteristics with particular effect on soil erodibility, through improvement of soil organic matter status, increase of soil biological activity and improvement of soil permeability. These soil factors improve e.g. soil structure stability and therefore reduce soil sealing risks. The effect of improvement of soil characteristics vis-a-vis soil erodibility is found to be most pronounced with Ferralsols and the following ferric/ferralic and plinthic soil units: Qf, Bf, Pf, Lf, Af, Gp, Lp and Ap. For these soil units the established reference K-factor on a scale of seven classes (FAO/IIASA 1991) has been reduced by one class.

4.5 Results of Primary Land Productivity Assessment

This section describes the productivity assessment of rainfed production potential with an example, followed by tabulated regional level results of the crop productivity assessment.

4.5.1 Example of Calculation Procedures

For the purpose of the demonstration of various steps in the calculation of land productivity, an AEZ cell, situated near Zaria in Nigeria, was selected from the land resources data base. This AEZ cell is characterized by the following land resources information:

Component	Code	Description
Country	159	Nigeria
Thermal zone	1	Warm tropics (T_{mean} >20 °C
Length of growing period Zone	G	LGP 180-210 days
Soil association	Lf49-1a	40% Lf; 20% Af; 20% I; 10% Ge; 10% Lp
Soil unit	Lf	Ferric Luvisol
Soil texture	1	coarse
Soil phase	20	none
Terrain slope	a2	2-8%
Ecosystem	6	farmland
Protected area	0	none
Human settlement area (yr. 2010)		14,300 ha
AEZ cell extent		349,700 ha

The crop considered in this example is 120 day lowland maize and is assumed to be grown under intermediate level of inputs and technology (see Table 3.1). Further it is assumed that forage legume fallows are used to regenerate soil fertility, break pest and disease cycles and provide additional high quality fodder for livestock. The calculations procedures comprise the following steps:

(1) Lowland maize is fully adapted to the prevailing temperature regime in the selected AEZ cell - Warm tropics (T_{mean} >20 °C)

(2) The maximum constraint-free biomass and yield are calculated according to the prevailing temperature and radiation regime according to AEZ method described in Section 3.5.2 and FAO (1978). The biomass thus obtained is 20.1 t/ha and the grain yield 7.0 t/ha. For intermediate level of inputs the attainable constraint-free .yield has been adjusted for reasons of sub-optimal application of fertilizer and limited pest, disease and weed control (FAO 1978).

(3) The agronomically attainable yield at intermediate level of inputs, for a sole crop of maize in LGP zone 180-210 days with no or only very slight occurrence of agro-climatic constraints (pest and diseases), is assessed to be 4.4 t/ha (Agro-climatic suitability class, Very Suitable).

(4) Additional yield from sequential cropping possibilities provides an extra 0.5 t/ha. Benefits from intercropping are estimated to contribute some extra 15 % percent yield increment. The production of this AEZ cell from climatic viewpoint (assuming there are no soil and terrain constraints) amounts then 5.7 t/ha.

(5) The soil unit rating of Ferric Luvisol is S1/S2, i.e. the soil unit limitations affect maize production and depress yields in the order 33%. The medium texture and the absence of soil phases do not further affect the yield.

(6) The average slope gradient of 5% (average from slope class 2-8% recorded for the AEZ cell) passes the slope cultivation association screen (Table 4.5), and therefore the AEZ cell/LUT combination is tested on topsoil loss and possible productivity loss.

(7) Topsoil loss under maize without conservation measures, for the soil, terrain and climate conditions prevailing in this AEZ cell is estimated 0.5 mm/yr. and appears to be less than annual the potential topsoil regeneration (1.2 mm). Therefore no net topsoil loss and no loss of productivity is to be considered .

(8) Assuming sown forage legume fallow being applied (verano stylo) this would equate for Ferric Luvisols, under the assumed intermediate level of inputs, to two years of fallow out of 10 years. This leads to a 20% reduction of maize production on a yearly basis.

(9) Step 1 to 8 provides the assessment of maize (grain) productivity.

(10) In addition to the grain yield, from the consumable portion of the residues of the maize, some 2.7 t/ha consumable fodder is produced[2] (also on a yearly basis).

(11) From the forage legume fallow, on a yearly basis, some extra 1.8 t/ha fodder can be obtained from fallow grazing.

The calculation of potential maize productivity of maize for the selected AEZ cell under the management conditions described is summarized below.

(2)	Constraint-free yield at intermediate level of inputs	4.4 t/ha
(3)	Agro-climatic attainable yield of sole maize crop	4.4 t/ha
(4)	Sequential cropping effects for LGP 180-210 days	+ 0.5 t/ha
(4)	Intercropping effects for LGP 180-210 days	+ 0.8 t/ha
(5)	Soil related constraints (S1/S2; 33%)	- 1.8 t/ha
(6)	Slope cultivation requirements (pass)	
(7)	Top soil loss - Productivity loss	- 0.0 t/ha
(8)	Fallow period requirements (-20%)	- 0.8 t/ha
		------------
(9)	Land productivity for lowland maize (grain)	3.0 t/ha
(10)	Land productivity for lowland maize (consumable residue for livestock)	2.7 t/ha
(11)	Land productivity from forage legume fallow(fallow grazing)	1.8 t/ha

2 For details on conversions of fodder production to livestock production reference should be made of Volume 2 of this report.

4.5.2 Results of Primary Land Productivity Assessment

The calculation procedures have been performed for all food crop-, forage legume- and pasture LUTs for each of the 44,039 AEZ cells in West Africa. The extent and productivity class of each LUT are recorded by AEZ cell. This information is then aggregated to sub-national climatic zones level (hyperarid, arid, dry semi-arid, moist semi-arid, subhumid and humid), country level and regional level. Six sets of aggregated results of potential primary land productivity for the West African Region presented in Tables 4.9-4.14, are based on the following general assumptions:

- intermediate level of inputs and technology
- adoption rates for the incorporation of forage legumes in cropping systems (forage legumes as fallow crops and intercrops) are 0%, 20% and 100%.
- human settlement requirements of populations projected for 2010
- no production from protected areas
- sustainable production systems including appropriate fallows and tolerable levels of soil loss.

Each set of results sets comprise of specific assumptions as follows:

Set 1: Primary productivity of food crops without forage legumes (0% adoption) in cropping system with soil conservation measures.

Set 2: As Set 1, without soil conservation measures as defined for intermediate level of inputs.

Set 3: Primary productivity of food crops with some forage legumes (20% adoption) in cropping system with soil conservation measures.

Set 4: As Set 3, without soil conservation measures as defined for intermediate level of inputs.

Set 5: Primary productivity of food crops with forage legumes (100% adoption) in cropping system with soil conservation measures.

Set 6: As Set 5, without soil conservation measures as defined for intermediate level of inputs.

In the tables potential primary land productivity from 'crop land' and 'fallow land' are given separately.

Estimated extents of 'crop land' are presented for individual crops, forage legumes and pastures in three productivity classes. These classes, (VS), (S) and (MS) represent potential productivities of respectively >80%, 40-80% and 20-40%, compared to maximum constraint-free productivity. The 'crop yield' column represents the average yield including multiple cropping increments. The 'production' columns present (a) production from individual crops, forage legumes and pastures and (b) production from forage legumes as intercrop if applicable.

Estimated extents of 'fallow land' are given separately for natural grass/bush fallows and forage legumes if applicable. The 'production' columns present production from fallow land from natural grass/bush fallow and from forage legumes if applicable.

In addition to the above, total and total net potential arable land extents have been calculated from all land suitable for crops (thus excluding forage legumes and pastures) The algorithm used to determine these arable land extents, selects in each AEZ cell, among all productive crops the crop that maximizes the weighted sum of extents in the land productivity classes VS, S, and MS. That maximum extent is than used to describe the potential arable land of a particular AEZ cell. The cell estimates of arable land aggregated by climatic zones for West Africa Region are presented in Tables 4.15 an 4.16. Table 4.15 presents total potential arable land with and without assumed soil conservation measures. Table 4.16 presents in the same way net total potential arable land which is excluding all land in protected areas and land required for human settlements.

Table 4.9 **PRIMARY LAND PRODUCTIVITY AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY: ASSUMPTION SET 1 - WITH SOIL CONSERVATION MEASURES AND WITHOUT FORAGE LEGUMES IN CROPPING SYSTEMS (0 % ADOPTION)**

	Crop Land							Fallow Land			
	Area (1000 ha)				Crop Yield[1]	Production (1000 tons)		Area (1000 ha)		Production (1000 tons)	
CROP	VS	S	MS	TOTAL	t/ha	CROP	FOR.LEG[2]	NAT.F[4]	FOR.LEG[3]	NAT.F[4]	FOR.LEG[3]
MILLET	8337	37240	46945	92522	2.0	186929	0	30000	0	56309	0
SORGHUM	19251	40198	34922	94371	2.6	241526	0	29747	0	58113	0
MAIZE	21320	46560	47026	114906	3.5	398515	0	38005	0	94431	0
SOYBEAN	17502	38953	35966	92421	1.7	161251	0	29451	0	65419	0
PHAS.BEAN	18667	39407	35991	94065	1.7	161452	0	30267	0	66528	0
COTTON	17802	35732	30849	84382	0.5	45128	0	26921	0	55653	0
SWEET POTATO	8518	48518	38957	95994	14.7	1412869	0	31376	0	87868	0
CASSAVA	6901	29108	33721	69729	26.5	1849308	0	24754	0	81548	0
WETLAND RICE	0	11371	24343	35714	6.0	213828	0	11313	0	41377	0
SPRING WHEAT	1	31	45	77	2.5	193	0	24	0	83	0
WHITE POTATO	0	11	59	71	16.3	1160	0	22	0	80	0
BARLEY	0	3	31	34	1.5	52	0	10	0	36	0
DRYLAND RICE	12452	45706	47260	105418	4.3	455892	0	35675	0	105342	0
GROUNDNUT	21374	47066	36928	105368	2.8	299585	0	34628	0	75369	0
BANANA/PLANT	494	12032	15989	28514	14.4	411840	0	10036	0	42143	0
SUGARCANE	1159	21315	30779	53253	43.7	2327125	0	18498	0	70913	0
OILPALM	1387	13877	26449	41713	2.3	97103	0	0	0	0	0
COWPEA	7597	43829	45672	97098	1.4	133595	0	32222	0	84467	0
MAIWA MILLET	13834	38817	34505	87156	1.5	129694	0	27834	0	58771	0
PH.PER.SORGH	14157	36102	29213	79472	2.3	185714	0	24982	0	53327	0
VERANO STYLO	9393	52620	66816	128830	4.5	576278	0	43680	0	126734	0
CHAMAECRISTA	13285	57050	70100	140435	4.1	572022	0	47299	0	132955	0
CENTROSEMA	16761	62118	59799	138677	4.1	554576	0	46305	0	133680	0
LABLAB	5414	26784	34992	67191	4.0	265944	0	21181	0	57223	0
SIRATRO	11578	50651	63546	125776	4.0	499814	0	41543	0	117405	0
FORAGE VIGNA	16761	59906	54065	130732	2.8	351456	0	44301	0	127695	0
SOWN PASTURE	20384	93110	69762	183255	5.8	1061289	0	0	0	0	0
NAT.PASTURE	38268	99733	91390	229391	7.4	1687236	0	0	0	0	0

[1] sweet potato, cassava, white potato,banana/plantain and sugarcane - fresh weight; others - dry weight.
[2] FOR.LEG = forage legume intercrop. [3] FOR.LEG = forage legume fallow. [4] NAT.F = natural grass/bush fallow.

Table 4.10 PRIMARY LAND PRODUCTIVITY AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY: ASSUMPTION SET 2 - WITHOUT SOIL CONSERVATION MEASURES AND WITHOUT FORAGE LEGUMES IN CROPPING SYSTEMS (0 % ADOPTION)

	Crop Land							**Fallow Land**			
	Area (1000 ha)				Crop Yield[1]	Production (1000 tons)		Area (1000 ha)		Production (1000 tons)	
CROP	VS	S	MS	TOTAL	t/ha	CROP	FOR.LEG[2]	NAT.F[4]	FOR.LEG[3]	NAT.F[4]	FOR.LEG[3]
MILLET	6412	29410	36708	72530	1.4	102300	0	23546	0	84707	0
SORGHUM	14814	32405	25013	72231	1.9	138341	0	22672	0	84282	0
MAIZE	16144	37060	32020	85224	2.6	218233	0	28143	0	133051	0
SOYBEAN	12923	29938	25377	68238	1.3	86258	0	21670	0	91282	0
PHAS.BEAN	13703	30210	25084	68997	1.3	88505	0	22173	0	93304	0
COTTON	13503	27919	21939	63361	0.4	27028	0	20200	0	79237	0
SWEET POTATO	3620	35029	28281	66930	10.2	686023	0	21584	0	116370	0
CASSAVA	4394	17190	19688	41272	18.9	780504	0	14749	0	94094	0
WETLAND RICE	0	11371	24343	35714	6.0	213828	0	11313	0	82754	0
SPRING WHEAT	1	8	16	25	1.7	42	0	8	0	57	0
WHITE POTATO	0	4	25	28	9.9	276	0	9	0	67	0
BARLEY	0	1	9	10	1.0	10	0	3	0	22	0
DRYLAND RICE	8931	27997	31507	68435	2.8	194049	0	22731	0	123714	0
GROUNDNUT	14905	35710	25990	76605	2.1	158136	0	25187	0	104557	0
BANANA/PLANT	494	12032	15989	28514	14.4	411840	0	10036	0	84286	0
SUGARCANE	1159	21315	30779	53253	43.7	2326169	0	18498	0	141825	0
OILPALM	1387	13877	26449	41713	2.3	97103	0	0	0	0	0
COWPEA	3084	32992	32941	69017	0.9	64866	0	22861	0	116010	0
MAIWA MILLET	8294	28498	26612	63403	1.0	66006	0	20253	0	79399	0
PH.PER.SORGH	9330	27862	22549	59742	1.7	99734	0	18704	0	73551	0
VERANO STYLO	9393	51750	65984	127127	4.3	549538	0	43215	0	251793	0
CHAMAECRISTA	13285	55718	69105	138108	3.9	543388	0	46663	0	263672	0
CENTROSEMA	16761	62118	59483	138361	3.9	536869	0	46219	0	267079	0
LABLAB	5414	26703	34328	66445	3.8	250294	0	20977	0	113707	0
SIRATRO	11578	49768	62224	123571	3.8	473649	0	40936	0	232575	0
FORAGE VIGNA	16761	59773	52842	129375	2.6	339383	0	43912	0	253674	0
SOWN PASTURE	20264	92610	68966	181840	5.6	1020894	0	0	0	0	0
NAT.PASTURE	38262	98821	87999	225081	7.3	1648328	0	0	0	0	0

1 sweet potato, cassava, white potato,banana/plantain and sugarcane - fresh weight; others - dry weight.
2 FOR.LEG = forage legume intercrop. 3 FOR.LEG = forage legume fallow. 4 NAT.F = natural grass/bush fallow.

Table 4.11 PRIMARY LAND PRODUCTIVITY AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY: ASSUMPTION SET 3 - WITH SOIL CONSERVATION MEASURES AND WITH FORAGE LEGUMES IN CROPPING SYSTEMS (20 % ADOPTION)

	Crop Land							Fallow Land			
	Area (1000 ha)				Crop Yield[1]	Production (1000 tons)		Area (1000 ha)		Production (1000 tons)	
CROP	VS	S	MS	TOTAL	t/ha	CROP	FOR.LEG[2]	NAT.F[4]	FOR.LEG[3]	NAT.F[4]	FOR.LEG[3]
MILLET	8339	38090	47898	94327	2.0	186669	7819	27453	2582	50510	5296
SORGHUM	20037	41072	35183	96292	2.5	240135	13484	26533	3153	50501	6645
MAIZE	21470	46878	47348	115696	3.4	388567	19906	32586	4629	79987	9539
SOYBEAN	18095	40082	36311	94487	1.7	160218	17559	25380	3884	54716	8457
PHAS.BEAN	18932	40055	36331	95318	1.7	158579	17680	25880	3925	55485	8542
COTTON	17941	36145	31327	85413	0.5	44103	15142	22868	3597	46270	7575
SWEET POTATO	8596	49281	39181	97058	14.2	1381910	22182	26517	4283	73756	9304
CASSAVA	6982	29413	34013	70408	25.6	1799007	17941	20352	3743	67933	8329
WETLAND RICE	0	11421	24505	35926	5.8	208443	6024	9556	1545	35558	3372
SPRING WHEAT	1	31	45	77	2.4	186	0	24	0	83	0
WHITE POTATO	0	11	59	71	15.9	1127	0	22	0	80	0
BARLEY	0	3	31	34	1.5	51	0	10	0	36	0
DRYLAND RICE	12587	46135	47630	106351	4.2	443636	20569	29900	4902	88800	10044
GROUNDNUT	21535	47395	37153	106083	2.8	292304	18140	29837	4077	63289	8501
BANANA/PLANT	498	12092	16103	28692	13.8	396023	3255	8873	985	37293	1951
SUGARCANE	1166	21447	31063	53676	42.0	2252674	8650	15707	2368	60679	5022
OILPALM	1387	13877	26449	41713	2.2	93546	3424	0	0	0	0
COWPEA	7657	44504	45964	98124	1.3	130790	18706	27765	3942	71818	8555
MAIWA MILLET	14644	39819	34743	89207	1.5	129930	16754	23995	3681	49221	7918
PH.PER.SORGH	14966	37096	29423	81485	2.3	186166	16707	21223	3612	44111	7680
VERANO STYLO	9393	52620	66816	128830	4.5	576278	0	43680	0	126734	0
CHAMAECRISTA	13285	57050	70100	140435	4.1	572022	0	47299	0	132955	0
CENTROSEMA	16761	62118	59799	138677	4.3	554576	0	46305	0	133680	0
LABLAB	5414	26784	34992	67191	3.9	265944	0	21181	0	57223	0
SIRATRO	11578	50651	63546	125776	4.0	499814	0	41543	0	117405	0
FORAGE VIGNA	16761	59906	54065	130732	2.8	351456	0	44301	0	127695	0
SOWN PASTURE	20384	93110	69762	183255	5.8	1061289	0	0	0	0	0
NAT.PASTURE	38268	99733	91390	229391	7.4	1687236	0	0	0	0	0

[1] sweet potato, cassava, white potato,banana/plantain and sugarcane - fresh weight; others - dry weight.
[2] FOR.LEG = forage legume intercrop. [3] FOR.LEG = forage legume fallow. [4] NAT.F = natural grass/bush fallow.

Table 4.12 PRIMARY LAND PRODUCTIVITY AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY: ASSUMPTION SET 4 - WITHOUT SOIL CONSERVATION MEASURES AND WITH FORAGE LEGUMES IN CROPPING SYSTEMS (20 % ADOPTION)

	Crop Land							Fallow Land			
	Area (1000 ha)				Crop Yield[1]	Production (1000 tons)		Area (1000 ha)		Production (1000 tons)	
CROP	VS	S	MS	TOTAL	t/ha	CROP	FOR.LEG[2]	NAT.F[4]	FOR.LEG[3]	NAT.F[4]	FOR.LEG[3]
MILLET	6414	29616	37006	73036	1.4	101030	5531	21484	1839	76351	7048
SORGHUM	14915	32805	25421	73141	1.9	135908	9197	20273	2229	74122	8770
MAIZE	16253	37296	32204	85752	2.5	214696	12760	24475	3142	114650	12083
SOYBEAN	13107	30696	25776	69580	1.2	85089	11342	18854	2680	77648	10916
PHAS.BEAN	13797	30428	25232	69457	1.3	87091	11409	19043	2694	78314	11026
COTTON	13609	28301	22344	64254	0.4	26532	10002	17366	2567	66930	10070
SWEET POTATO	3671	35624	28492	67787	10.0	674998	13108	18630	2678	100449	11020
CASSAVA	4485	17426	19881	41792	18.5	771157	9585	12315	2109	79941	9021
WETLAND RICE	0	11421	24505	35926	5.8	208443	6024	9556	1545	71117	6744
SPRING WHEAT	1	8	16	25	1.6	41	0	8	0	57	0
WHITE POTATO	0	4	25	28	9.6	269	0	9	0	67	0
BARLEY	0	1	9	10	1.0	10	0	3	0	22	0
DRYLAND RICE	9023	28246	31687	68955	2.8	191869	11085	19302	2910	105895	11217
GROUNDNUT	15017	35935	26167	77119	2.0	155884	11231	21957	2760	88922	10661
BANANA/PLANT	498	12092	16103	28692	13.8	396023	3255	8873	985	74586	3901
SUGARCANE	1166	21447	31063	53676	42.0	2252299	8650	15707	2368	121358	10045
OILPALM	1387	13877	26449	41713	2.2	93546	3424	0	0	0	0
COWPEA	3107	34139	33366	70612	0.9	63755	11676	20286	2563	102142	10624
MAIWA MILLET	8713	29215	26737	64664	1.0	65493	10297	17681	2447	67851	9862
PH.PER.SORGH	9438	28070	22635	60143	1.6	99009	10497	15868	2440	61165	9662
VERANO STYLO	9393	51750	65984	127127	4.3	549538	0	43215	0	251793	0
CHAMAECRISTA	13285	55718	69105	138108	3.9	543388	0	46663	0	263672	0
CENTROSEMA	16761	62118	59483	138361	3.9	536869	0	46219	0	267079	0
LABLAB	5414	26703	34328	66445	3.8	250294	0	20977	0	113707	0
SIRATRO	11578	49768	62224	123571	3.8	473649	0	40936	0	232575	0
FORAGE VIGNA	16761	59773	52842	129375	2.6	339383	0	43912	0	253674	0
SOWN PASTURE	20264	92610	68966	181840	5.6	1020894	0	0	0	0	0
NAT.PASTURE	38262	98821	87999	225081	7.3	1648328	0	0	0	0	0

[1] sweet potato, cassava, white potato,banana/plantain and sugarcane - fresh weight; others - dry weight.
[2] FOR.LEG = forage legume intercrop. [3] FOR.LEG = forage legume fallow. [4] NAT.F = natural grass/bush fallow.

Table 4.13 PRIMARY LAND PRODUCTIVITY AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY: ASSUMPTION SET 5 - WITH SOIL CONSERVATION MEASURES AND WITH FORAGE LEGUMES IN CROPPING SYSTEMS (100 % ADOPTION)

	Crop Land							Fallow Land			
	Area (1000 ha)				Crop Yield[1]	Production (1000 tons)		Area (1000 ha)		Production (1000 tons)	
CROP	VS	S	MS	TOTAL	t/ha	CROP	FOR.LEG[2]	NAT.F[4]	FOR.LEG[3]	NAT.F[4]	FOR.LEG[3]
MILLET	8349	39003	49344	96696	1.8	169313	39621	17125	11397	28411	23360
SORGHUM	20863	42509	36050	99423	2.1	207650	68775	13921	13959	22133	29416
MAIZE	22404	48889	49007	120299	2.8	335794	101356	14071	20364	30598	41979
SOYBEAN	18958	41818	37512	98288	1.4	138841	89444	9845	17104	15821	37246
PHAS.BEAN	19690	42066	37634	99390	1.4	137273	90002	10179	17362	16439	37666
COTTON	18626	37656	32641	88923	0.4	37770	76886	8478	15852	13107	33210
SWEET POTATO	8908	51134	40329	100370	11.6	1160945	111840	9384	18779	24437	40791
CASSAVA	7353	30682	35551	73586	20.4	1503534	90467	5381	16204	21646	36204
WETLAND RICE	0	11619	25153	36772	4.9	181114	30120	3376	6879	15144	14925
SPRING WHEAT	1	31	45	77	2.1	161	0	24	0	83	0
WHITE POTATO	0	11	59	71	14.0	995	0	22	0	80	0
BARLEY	0	3	31	34	1.4	46	0	10	0	36	0
DRYLAND RICE	13122	48608	49701	111431	3.4	376337	104710	10291	21348	32621	43903
GROUNDNUT	22625	49595	38167	110387	2.3	253169	92664	13528	17891	22156	37271
BANANA/PLANT	513	12333	16558	29404	11.0	322097	16277	4934	4211	20851	8401
SUGARCANE	1193	21976	32199	55368	34.0	1882491	43251	6235	10148	25882	21625
OILPALM	1387	13877	26449	41713	1.9	77321	17120	0	0	0	0
COWPEA	7906	46253	47163	101322	1.1	112168	94504	11998	17299	27496	37523
MAIWA MILLET	15732	41640	35509	92881	1.2	114017	85518	9271	16185	14309	34846
PH.PER.SORGH	16051	38944	30093	85088	1.9	162937	85288	6773	15915	10311	33871
VERANO STYLO	9393	52620	66816	128830	4.5	576278	0	43680	0	126734	0
CHAMAECRISTA	13285	57050	70100	140435	4.1	572022	0	47299	0	132955	0
CENTROSEMA	16761	62118	59799	138677	4.0	554576	0	46305	0	133680	0
LABLAB	5414	26784	34992	67191	4.0	265944	0	21181	0	57223	0
SIRATRO	11578	50651	63546	125776	4.0	499814	0	41543	0	117405	0
FORAGE VIGNA	16761	59906	54065	130732	2.7	351456	0	44301	0	127695	0
SOWN PASTURE	20384	93110	69762	183255	5.8	1061289	0	0	0	0	0
NAT.PASTURE	38268	99733	91390	229391	7.4	1687236	0	0	0	0	0

[1] sweet potato, cassava, white potato,banana/plantain and sugarcane - fresh weight; others - dry weight.
[2] FOR.LEG = forage legume intercrop. [3] FOR.LEG = forage legume fallow. [4] NAT.F = natural grass/bush fallow.

Table 4.14 PRIMARY LAND PRODUCTIVITY AT INTERMEDIATE LEVEL OF INPUTS AND TECHNOLOGY: ASSUMPTION SET 6 - WITHOUT SOIL CONSERVATION MEASURES AND WITH FORAGE LEGUMES IN CROPPING SYSTEMS (100 % ADOPTION)

	Crop Land							Fallow Land			
	Area (1000 ha)				Crop Yield[1]	Production (1000 tons)		Area (1000 ha)		Production (1000 tons)	
CROP	VS	S	MS	TOTAL	t/ha	CROP	FOR.LEG[2]	NAT.F[4]	FOR.LEG[3]	NAT.F[4]	FOR.LEG[3]
MILLET	6438	30094	38627	75159	1.3	93843	28110	14129	8255	46564	31832
SORGHUM	15376	33991	26770	76136	1.6	120654	47531	11358	10120	35989	40094
MAIZE	16679	39249	35213	91140	2.1	191821	67621	11908	14452	51568	55997
SOYBEAN	13558	32398	27436	73391	1.0	76683	59429	8135	12167	26007	49830
PHAS.BEAN	14199	32544	27895	74638	1.0	77853	61084	8269	12572	26633	51632
COTTON	14624	30215	24297	69136	0.3	23418	53715	7100	11940	22014	46587
SWEET POTATO	3871	38247	29400	71518	8.3	596676	68679	7918	12272	42367	50446
CASSAVA	4928	19094	21337	45358	15.3	693326	50930	3879	9606	31117	41145
WETLAND RICE	0	11619	25153	36772	4.9	181114	30120	3376	6879	30288	29851
SPRING WHEAT	1	8	16	25	1.4	36	0	8	0	57	0
WHITE POTATO	0	4	25	28	8.6	241	0	9	0	67	0
BARLEY	0	1	9	10	0.9	9	0	3	0	22	0
DRYLAND RICE	10352	31193	33249	74793	2.3	175483	60780	7661	13475	45235	52338
GROUNDNUT	15498	38552	28452	82503	1.7	140496	60657	10918	12767	35524	49722
BANANA/PLANT	513	12333	16558	29404	11.0	322097	16277	4934	4211	41702	16803
SUGARCANE	1193	21976	32199	55368	34.0	1882491	43251	6235	10148	51763	43249
OILPALM	1387	13877	26449	41713	1.9	77321	17120	0	0	0	0
COWPEA	3200	35481	35514	74195	0.8	56771	60639	10033	11724	47299	48481
MAIWA MILLET	9507	30981	27732	68221	0.9	60370	54183	7894	11097	24033	45028
PH.PER.SORGH	10263	30342	24085	64689	1.4	91021	56303	6108	11358	18324	45359
VERANO STYLO	9393	51750	65984	127127	4.3	549538	0	43215	0	251793	0
CHAMAECRISTA	13285	55718	69105	138108	3.9	543388	0	46663	0	263672	0
CENTROSEMA	16761	62118	59483	138361	3.9	536869	0	46219	0	267079	0
LABLAB	5414	26703	34328	66445	3.8	250294	0	20977	0	113707	0
SIRATRO	11578	49768	62224	123571	3.8	473649	0	40936	0	232575	0
FORAGE VIGNA	16761	59773	52842	129375	2.6	339383	0	43912	0	253674	0
SOWN PASTURE	20264	92610	68966	181840	5.6	1020894	0	0	0	0	0
NAT.PASTURE	38262	98821	87999	225081	7.3	1648328	0	0	0	0	0

[1] sweet potato, cassava, white potato,banana/plantain and sugarcane - fresh weight; others - dry weight.
[2] FOR.LEG = forage legume intercrop. [3] FOR.LEG = forage legume fallow. [4] NAT.F = natural grass/bush fallow.

Table 4.15 TOTAL POTENTIAL ARABLE LAND (1000 ha)

EXTENTS	With Conservation Measures VS	S	MS	ARABLE	NS	TOTAL	Without Conservation Measures VS	S	MS	ARABLE	NS	Losses ARABLE
Hyperarid	0	0	0	0	194581	194581	0	0	0	0	194581	0
Arid	0	444	395	839	178267	179106	0	444	395	839	178267	0
Dry Semiarid	0	9031	19959	28990	35584	64573	0	7469	15672	23141	41433	5849
Moist Semiarid	27328	38381	5941	71650	44344	115993	21269	31681	4909	57859	58135	13791
Subhumid	30411	46551	8633	85595	40902	126496	18677	32232	5695	56605	69892	28990
Humid	11688	39063	17113	67864	35614	103478	10487	29071	8416	47973	55505	19890
Undefined	0	0	0	0	5140	5140	0	0	0	0	5140	0
TOTAL	69427	133468	52042	254937	534431	789368	50433	100896	35087	186416	602952	68521

Table 4.16 NET POTENTIAL ARABLE LAND (1000 ha)

EXTENTS	With Conservation Measures VS	S	MS	ARABLE	NS	TOTAL	Without Conservation Measures VS	S	MS	ARABLE	NS	Losses ARABLE
Hyperarid	0	0	0	0	185838	194581	0	0	0	0	185838	0
Arid	0	436	386	822	174852	179089	0	436	386	822	174852	0
Dry Semiarid	0	8549	18812	27361	33028	62945	0	7095	14794	21889	38501	5473
Moist Semiarid	25189	35395	5611	66195	40715	110539	19641	29212	4646	53500	53411	12696
Subhumid	27793	42182	7762	77737	36944	118638	16919	28964	4990	50872	63809	26865
Humid	10760	36040	15874	62674	32723	98288	9625	26778	7727	44130	51266	18543
Undefined	0	0	0	0	5140	5140	0	0	0	0	5140	0
Net Total	63742	122602	48445	234788	509241	744029	46185	92485	32542	171212	572817	63576
Protected Areas	3303	6290	1979	11572	17366	28938	2491	4958	1488	8937	20001	2635
Habitation Areas	2383	4576	1618	8577	7824	16401	1756	3454	1058	6268	10134	2309
TOTAL	69427	133468	52042	254937	534431	789368	50433	100896	35087	186416	602952	68521

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APPENDIX 3

LAND SUITABLITY

Table 1.1 AVERAGE AGRO-CLIMATIC CROP SUITABILITY (Single crop yields in t/ha)

	Input Level	Length of Growing Period (days) 75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Pearl Millet	High	1.4	3.1	3.0	3.9	2.8	1.6	0.5	0.5	0.4	0.4	0.4
	Int.	0.9	2.0	2.0	2.5	1.8	1.1	0.4	0.4	0.3	0.3	0.3
	Low	0.4	0.8	0.8	1.0	0.7	0.5	0.2	0.2	0.2	0.2	0.2
Sorghum (lowland)	High	0.9	1.3	3.8	5.1	5.0	2.7	1.2	0.9	0.6	0.6	0.6
	Int.	0.5	1.4	2.3	3.2	3.2	1.7	0.8	0.6	0.4	0.4	0.4
	Low	0.2	0.5	0.7	1.3	1.3	0.7	0.3	0.2	0.2	0.2	0.2
Sorghum (highland)	High	0.1	0.5	1.5	2.8	3.7	4.1	3.3	2.3	1.6	1.0	1.0
	Int.	0.1	0.3	1.0	1.8	2.3	2.6	2.1	1.6	1.1	0.6	0.6
	Low	0	0.1	0.3	0.7	0.9	1.0	0.8	0.8	0.5	0.2	0.2
Maize (lowland)	High	0.9	2.3	5.4	7.1	7.0	5.1	3.4	2.5	2.4	1.8	1.8
	Int.	0.5	1.4	3.2	4.5	4.4	3.2	2.2	1.7	1.7	1.3	1.3
	Low	0.2	0.5	1.0	1.8	1.7	1.3	1.0	0.9	0.9	0.7	0.7
Maize (highland)	High	0.1	0.7	2.2	4.0	5.1	6.5	6.2	6.1	4.8	3.0	3.0
	Int.	0.1	0.4	1.4	2.5	3.2	4.1	3.9	3.9	3.2	1.9	1.9
	Low	0	0.2	0.5	1.0	1.3	1.6	1.6	1.7	1.5	0.8	0.8
Soybean	High	0.5	1.1	2.5	3.4	3.3	2.5	1.6	1.2	0.9	0.6	0.6
	Int.	0.3	0.7	1.6	2.1	2.0	1.5	1.1	0.8	0.6	0.5	0.4
	Low	0.1	0.3	0.6	0.8	0.6	0.5	0.5	0.3	0.2	0.1	0.1
Ph.bean (lowland)	High	0.5	1.1	2.5	3.4	3.3	2.5	1.6	1.2	0.9	0.6	0.6
	Int	0.3	0.7	1.6	2.1	2.0	1.5	1.0	0.7	0.6	0.4	0.4
	Low	0.1	0.3	0.6	0.8	0.6	0.5	0.3	0.2	0.2	0.1	0.1
Ph.bean (highland)	High	0.2	0.5	1.1	2.7	3.0	2.5	2.3	1.1	0.8	0.6	0.6
	Int	0.1	0.3	0.7	1.7	1.8	1.5	1.3	0.7	0.5	0.4	0.4
	Low	0.1	0.2	0.3	0.7	0.6	0.4	0.3	0.2	0.2	0.1	0.1

Table 1.1 CONTINUED

	Input Level	Length of Growing Period (days) 75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Sweet potato	High	0.9	2.1	4.5	10.1	9.9	9.7	9.7	7.1	3.5	3.4	2.3
	Int.	0.6	1.3	2.9	6.3	6.2	6.1	5.8	4.5	2.4	2.3	1.8
	Low	0.3	0.5	1.2	2.5	2.5	2.4	1.8	1.8	1.2	1.2	1.2
Cassava	High	0.3	0.6	1.5	3.5	8.8	10.9	11.9	12.4	13.2	7.4	7.4
	Int.	0.2	0.4	0.9	2.3	5.2	6.5	7.1	7.4	8.0	4.7	4.7
	Low	0.1	0.2	0.4	0.9	1.7	2.0	2.2	2.3	2.5	1.9	1.9
Rice (wetland)	High	0	0	0	2.0	2.9	3.9	3.9	3.9	3.8	3.8	3.8
	Int.	0	0	0	1.3	1.8	2.5	2.5	2.5	2.4	2.4	2.4
	Low	0	0	0	0.5	0.7	1.0	1.0	1.0	1.0	1.0	1.0
Spring wheat	High	0.2	0.9	2.5	4.3	5.6	4.0	2.3	0.8	0.7	0.7	0.7
	Int.	0.1	0.6	1.6	2.9	3.5	2.6	1.5	0.6	0.5	0.5	0.5
	Low	0.1	0.2	0.8	1.3	1.4	1.1	0.7	0.3	0.3	0.3	0.3
White potato	High	1.4	2.3	4.8	9.7	9.4	5.3	5.3	1.8	1.2	1.2	1.2
	Int	0.9	1.4	3.1	6.1	5.9	3.6	3.3	1.3	0.8	0.8	0.8
	Low	0.4	0.6	1.4	2.4	2.4	1.8	1.3	0.7	0.3	0.3	0.3
Rice (dryland)	High	0.3	0.8	1.1	1.6	2.4	3.2	4.2	4.2	4.1	3.0	2.3
	Int.	0.2	0.5	0.7	1.0	1.5	2.0	2.6	2.6	2.6	1.9	1.4
	Low	0.1	0.2	0.3	0.4	0.6	0.8	1.1	1.1	1.0	0.8	0.6
Cotton (lint)	High	0.0	0.1	0.6	1.1	1.1	0.6	0.5	0.3	0.2	0.1	0.1
	Int	0.0	0.06	0.34	0.63	0.63	0.38	0.33	0.19	0.13	0.07	0.07
	Low	0.0	0.02	0.08	0.16	0.16	0.15	0.15	0.07	0.05	0.03	0.03
Groundnut	High	0.5	1.1	1.9	3.3	3.3	3.3	1.9	1.4	1.2	0.9	0.6
	Int.	0.3	0.7	1.2	2.1	2.1	2.0	1.2	0.9	0.7	0.6	0.4
	Low	0.1	0.3	0.5	0.8	0.8	0.6	0.5	0.4	0.2	0.2	0.2

Table 1.1 CONTINUED

	Input Level	75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
		Length of Growing Period (days)										
Banana/Plantain	High	0	0	0	0	0	0.6	2.3	4.3	6.6	10.0	10.0
	Int.	0	0	0	0	0	0.4	1.4	2.7	4.1	6.3	6.3
	Low	0	0	0	0	0	0.2	0.6	1.1	1.7	2.5	2.5
Sugarcane	High	0	0.1	0.4	0.9	2.2	4.4	6.3	8.1	9.8	11.1	12.1
	Int.	0	0.1	0.2	0.6	1.4	2.8	4.0	5.1	6.1	6.9	7.6
	Low	0	0	0.1	0.2	0.6	1.1	1.6	2.0	2.4	2.8	3.0
Oilpalm	High	0	0	0	0	0	0.4	1.2	2.9	4.1	5.6	6.6
	Int.	0	0	0	0	0	0.3	0.8	1.8	2.6	3.5	4.2
	Low	0	0	0	0	0	0.1	0.3	0.7	1.1	1.4	1.7
Maiwa millet	High	0	0.6	1.5	2.4	3.4	3.1	1.6	0.7	0.5	0.5	0.3
	Int.	0	0.4	1.0	1.5	2.2	2.0	1.1	0.5	0.3	0.3	0.1
	Low	0	0.2	0.4	0.6	0.9	0.8	0.6	0.3	0.1	0.1	0.1
Sorghum[1] (lowland)	High	0	0.7	1.9	3.2	4.9	5.2	2.7	0.5	0.5	0.5	0.5
	Int.	0	0.5	1.2	2.0	3.2	3.3	1.9	0.4	0.4	0.4	0.3
	Low	0	0.2	0.5	0.8	1.3	1.3	1.0	0.2	0.2	0.2	0.1
Sorghum[1] (highland)	High	0	0.1	0.4	2.1	5.5	6.0	6.5	6.4	3.1	0.7	0.7
	Int.	0	0.1	0.3	1.3	3.5	3.9	4.1	3.8	1.8	0.5	0.5
	Low	0	0	0.1	0.5	1.4	1.7	1.6	1.1	0.4	0.2	0.2
Cowpea	High	0.5	1.2	2.2	2.2	2.9	2.2	2.1	2.1	2.1	1.6	0.7
	Int.	0.3	0.7	1.4	1.4	1.8	1.5	1.3	1.3	1.3	1.0	0.5
	Low	0.1	0.2	0.5	0.5	0.7	0.7	0.5	0.5	0.5	0.4	0.2
Verano stylo	High	0.1	0.8	2.2	6.4	9.5	11.9	11.1	9.5	7.2	6.0	6.0
	Int.	0.1	0.6	1.5	4.3	6.1	7.5	6.8	6.1	4.6	3.6	3.6
	Low	0.0	0.2	0.6	1.7	2.5	3.0	2.8	2.5	2.0	1.6	1.6

1 Photo-periodic cultivars

Table 1.1 CONTINUED

	Input Level	75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
		Length of Growing Period (days)										
Chamaecrista	High	0.4	1.1	4.2	6.7	8.9	10.9	8.1	8.1	5.7	5.7	5.7
	Int.	0.3	0.8	2.9	4.4	5.7	6.8	5.1	5.5	3.6	3.6	3.6
	Low	0.1	0.2	1.2	1.8	2.3	2.7	2.0	2.2	1.5	1.5	1.5
Centro	High	0.1	0.4	2.6	5.0	7.4	8.8	7.7	8.1	6.2	6.2	6.2
	Int.	0	0.3	1.9	3.9	5.1	6.0	5.1	5.4	4.0	4.0	4.0
	Low	0	0.1	0.8	1.6	2.0	2.4	2.0	2.2	1.6	1.6	1.6
Lablab	High	0.3	1.0	2.2	5.7	10.2	11.0	5.7	4.9	4.5	2.7	2.2
	Int.	0.3	0.8	1.6	3.6	6.7	7.0	3.2	3.1	2.6	1.7	1.5
	Low	0.1	0.3	0.6	1.4	2.7	2.8	1.3	1.1	1.0	0.7	0.6
Siratro	High	0.1	1.0	3.4	6.4	8.3	9.9	9.5	7.2	5.1	4.7	1.9
	Int.	0.1	0.7	2.3	4.4	5.5	6.5	5.2	4.7	3.3	3.0	1.1
	Low	0	0.3	0.9	1.8	2.2	2.6	2.3	2.1	1.4	1.3	0.4
Forage vigna	High	0.1	0.5	2.3	3.4	5.6	6.7	5.7	5.8	4.3	4.3	2.9
	Int.	0.0	0.3	1.5	2.1	3.5	4.2	3.4	3.6	2.7	2.7	1.8
	Low	0	0.1	0.6	1.1	1.4	1.7	1.4	1.5	1.1	1.1	0.7
Grasses, sown	High	0	0.2	2.1	6.7	10.3	12.7	12.7	12.7	12.7	9.5	9.5
	Int.	0	0.1	1.3	4.2	6.5	7.9	7.9	7.9	7.9	6.0	6.0
	Low	0	0	0.5	1.7	2.6	3.2	3.2	3.2	3.2	2.3	2.3
Grasses, natural	High	2.1	4.1	5.9	6.8	9.4	13.9	15.2	16.4	17.4	18.4	18.9
	Int.	1.4	2.3	3.3	3.9	5.4	8.0	8.7	9.4	10.0	10.5	10.8
	Low	0.7	0.8	1.2	1.4	2.0	2.9	3.2	3.4	3.6	3.8	3.9

Table 2.1 SOIL SUITABILITY RATINGS FOR VERANO STYLO

Soil Unit		Low	Int.	High
Gleysols	(G)	N2	N2	N2
Eutric Gleysols	(Ge)	N2	N2	N2
Calcaric Gleysols	(Gc)	N2	N2	N2
Dystric Gleysols	(Gd)	N2	N2	N2
Mollic Gleysols	(Gm)	N2	N2	N2
Humic Gleysols	(Gh)	N2	N2	N2
Plinthic Gleysols	(Gp)	N2	N2	N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S2	S2	S2
Dystric Regosols	(Rd)	S2	S1/S2	S1
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	S2/N2	S2/N2	S2/N2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	S2/N2	S2/N2	N2
Rankers	(U)	S2/N2	S2/N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	N2	N2	N2
Orthic Solonchaks	(Zo)	N2	N2	N2
Mollic Solonchaks	(Zm)	N2	N2	N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	N2	N2	N2
Orthic Solonetz	(So)	N2	N2	N2
Mollic Solonetz	(Sm)	N2	N2	N2
Gleyic Solonetz	(Sg)	N2	N2	N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	N2	N2	N2
Haplic Yermosols	(Yh)	N2	N2	N2
Calcic Yermosols	(Yc)	N2	N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	N2	N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S2	S2	S2
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S2	S2	S2
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S2	S2	S2
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S2	S2	S2
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	S1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S2	S1/S2	S1
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S2	S2	S2
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S2	S2	S2
Ferralic Cambisol	(Bf)	S2	S2	S2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S2	S2	S2

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S2	S2	S2
Ferric Luvisols	(Lf)	S2	S2	S2
Albic Luvisols	(La)	S2	S2	S2
Plinthic Luvisols	(Lp)	S2/N2	S2/N2	S2/N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S2	S1/S2	S1
Eutric Podzoluvisols	(De)	S2	S1/S2	S1
Dystric Podzoluvisols	(Dd)	S2	S2	S1/S2
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	N2	N2	N2
Orthic Podzols	(Po)	N2	N2	N2
Leptic Podzols	(Pl)	N2	N2	N2
Ferric Podzols	(Pf)	N2	N2	N2
Humic Podzols	(Ph)	N2	N2	N2
Placic Podzols	(Pp)	N2	N2	N2
Gleyic Podzols	(Pg)	N2	N2	N2
Planosols	(W)	S2	S2	S2
Eutric Planosols	(We)	S2	S2	S2
Dystric Planosols	(Wd)	S2/N2	S2/N2	S2
Mollic Planosols	(Wm)	S2	S2	S2
Humic Planosols	(Wh)	S2	S2	S2
Solodic Planosols	(Ws)	N2	N2	N2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2	S1/S2	S1
Orthic Acrisols	(Ao)	S2	S1/S2	S1
Ferric Acrisols	(Af)	S2	S2	S2
Humic Acrisols	(Ah)	S2	S1/S2	S1
Plinthic Acrisols	(Ap)	S2/N2	S2/N2	S2/N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S2	S1/S2	S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2	S2	S2
Orthic Ferralsols	(Fo)	S2	S2	S2
Xanthic Ferralsols	(Fx)	S2/N2	S2/N2	S2/N2
Rhodic Ferralsols	(Fr)	S2	S2	S2
Humic Ferralsols	(Fh)	S2	S2	S2
Acric Ferralsols	(Fa)	S2/N2	S2/N2	S2/N2
Plinthic Ferralsols	(Fp)	S2/N2	S2/N2	S2/N2
Histosols	(O)	N2	N2	N2
Eutric Histosols	(Oe)	N2	N2	N2
Dystric Histosols	(Od)	N2	N2	N2
Gelic Histosols	(Ox)	N2	N2	N2

Table 2.2 **SOIL SUITABILITY RATINGS FOR CHAMAECRISTA**

Soil Unit		Low	Int.	High
Gleysols	(G)	N2	N2	N2
Eutric Gleysols	(Ge)	N2	N2	N2
Calcaric Gleysols	(Gc)	N2	N2	N2
Dystric Gleysols	(Gd)	N2	N2	N2
Mollic Gleysols	(Gm)	N2	N2	N2
Humic Gleysols	(Gh)	N2	N2	N2
Plinthic Gleysols	(Gp)	N2	N2	N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S1/S2	S1/S2	S1/S2
Dystric Regosols	(Rd)	S1/S2	S1/S2	S1
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	S2/N2	S2/N2	S2/N2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	S2/N2	S2/N2	N2
Rankers	(U)	S2/N2	S2/N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	N2	N2	N2
Orthic Solonchaks	(Zo)	N2	N2	N2
Mollic Solonchaks	(Zm)	N2	N2	N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	N2	N2	N2
Orthic Solonetz	(So)	N2	N2	N2
Mollic Solonetz	(Sm)	N2	N2	N2
Gleyic Solonetz	(Sg)	N2	N2	N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	N2	N2	N2
Haplic Yermosols	(Yh)	N2	N2	N2
Calcic Yermosols	(Yc)	N2	N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	N2	N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S1/S2	S1/S2	S1/S2
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S1/S2	S1/S2	S1/S2
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S1/S2	S1/S2	S1/S2
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S1/S2	S1/S2	S1/S2
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S1/S2	S1/S2	S1
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S1/S2	S1/S2	S1/S2
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S2	S2	S2
Ferralic Cambisol	(Bf)	S2	S2	S2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S1/S2	S1/S2	S1/S2

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S2	S2	S2
Ferric Luvisols	(Lf)	S2	S2	S2
Albic Luvisols	(La)	S2	S2	S2
Plinthic Luvisols	(Lp)	S2/N2	S2/N2	S2/N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S2	S1/S2	S1
Eutric Podzoluvisols	(De)	S2	S1/S2	S1
Dystric Podzoluvisols	(Dd)	S2	S2	S1/S2
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	N2	N2	N2
Orthic Podzols	(Po)	N2	N2	N2
Leptic Podzols	(Pl)	N2	N2	N2
Ferric Podzols	(Pf)	N2	N2	N2
Humic Podzols	(Ph)	N2	N2	N2
Placic Podzols	(Pp)	N2	N2	N2
Gleyic Podzols	(Pg)	N2	N2	N2
Planosols	(W)	S2	S2	S2
Eutric Planosols	(We)	S2	S2	S2
Dystric Planosols	(Wd)	S2	S2	S2
Mollic Planosols	(Wm)	S2	S2	S2
Humic Planosols	(Wh)	S2	S2	S2
Solodic Planosols	(Ws)	N2	N2	N2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2	S1/S2	S1
Orthic Acrisols	(Ao)	S2	S1/S2	S1
Ferric Acrisols	(Af)	S2	S1/S2	S1
Humic Acrisols	(Ah)	S2	S1/S2	S1
Plinthic Acrisols	(Ap)	S2/N2	S2/N2	S2/N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S1/S2	S1/S2	S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2	S2	S2
Orthic Ferralsols	(Fo)	S2	S2	S2
Xanthic Ferralsols	(Fx)	S2/N2	S2/N2	S2/N2
Rhodic Ferralsols	(Fr)	S2	S2	S2
Humic Ferralsols	(Fh)	S2	S2	S2
Acric Ferralsols	(Fa)	S2/N2	S2/N2	S2/N2
Plinthic Ferralsols	(Fp)	S2/N2	S2/N2	S2/N2
Histosols	(O)	N2	N2	N2
Eutric Histosols	(Oe)	N2	N2	N2
Dystric Histosols	(Od)	N2	N2	N2
Gelic Histosols	(Ox)	N2	N2	N2

Table 2.3 SOIL SUITABILITY RATINGS FOR CENTROSEMA

Soil Unit		Low	Int.	High
Gleysols	(G)	S2/N2	S2/N2	S2/N2
Eutric Gleysols	(Ge)	S2/N2	S2/N2	S2/N2
Calcaric Gleysols	(Gc)	S2/N2	S2/N2	S2/N2
Dystric Gleysols	(Gd)	S2/N2	S2/N2	S2/N2
Mollic Gleysols	(Gm)	S2/N2	S2/N2	S2/N2
Humic Gleysols	(Gh)	S2/N2	S2/N2	S2/N2
Plinthic Gleysols	(Gp)	N2	N2	N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S1/S2	S1/S2	S1/S2
Dystric Regosols	(Rd)	S2	S1/S2	S1
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	S2/N2	S2/N2	S2/N2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	S2/N2	S2/N2	N2
Rankers	(U)	S2/N2	S2/N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	S2/N2	S2/N2	S2/N2
Orthic Solonchaks	(Zo)	S2/N2	S2/N2	S2/N2
Mollic Solonchaks	(Zm)	S2/N2	S2/N2	S2/N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	N2	N2	N2
Orthic Solonetz	(So)	N2	N2	N2
Mollic Solonetz	(Sm)	N2	N2	N2
Gleyic Solonetz	(Sg)	N2	N2	N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	N2	N2	N2
Haplic Yermosols	(Yh)	N2	N2	N2
Calcic Yermosols	(Yc)	N2	N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	N2	N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S1/S2	S1/S2	S1/S2
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S1/S2	S1/S2	S1/S2
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S1/S2	S1/S2	S1/S2
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S1/S2	S1/S2	S1/S2
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	S1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S2	S1/S2	S1
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S1/S2	S1/S2	S1/S2
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S2	S2	S2
Ferralic Cambisol	(Bf)	S2	S2	S2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S1/S2	S1/S2	S1/S2

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S2	S2	S2
Ferric Luvisols	(Lf)	S2	S2	S2
Albic Luvisols	(La)	S2	S2	S2
Plinthic Luvisols	(Lp)	S2/N2	S2/N2	S2/N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S2	S1/S2	S1
Eutric Podzoluvisols	(De)	S2	S1/S2	S1
Dystric Podzoluvisols	(Dd)	S2	S2	S1/S2
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	N2	N2	N2
Orthic Podzols	(Po)	N2	N2	N2
Leptic Podzols	(Pl)	N2	N2	N2
Ferric Podzols	(Pf)	N2	N2	N2
Humic Podzols	(Ph)	N2	N2	N2
Placic Podzols	(Pp)	N2	N2	N2
Gleyic Podzols	(Pg)	N2	N2	N2
Planosols	(W)	S2	S2	S2
Eutric Planosols	(We)	S2	S2	S2
Dystric Planosols	(Wd)	S2	S2	S2
Mollic Planosols	(Wm)	S2	S2	S2
Humic Planosols	(Wh)	S2	S2	S2
Solodic Planosols	(Ws)	N2	N2	N2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2	S1/S2	S1
Orthic Acrisols	(Ao)	S2	S1/S2	S1
Ferric Acrisols	(Af)	S2	S1/S2	S1
Humic Acrisols	(Ah)	S2	S1/S2	S1
Plinthic Acrisols	(Ap)	S2/N2	S2/N2	S2/N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S2	S1/S2	S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2	S2	S2
Orthic Ferralsols	(Fo)	S2	S2	S2
Xanthic Ferralsols	(Fx)	S2/N2	S2/N2	S2/N2
Rhodic Ferralsols	(Fr)	S2	S2	S2
Humic Ferralsols	(Fh)	S2	S2	S2
Acric Ferralsols	(Fa)	S2/N2	S2/N2	S2/N2
Plinthic Ferralsols	(Fp)	S2/N2	S2/N2	S2/N2
Histosols	(O)	N2	N2	N2
Eutric Histosols	(Oe)	N2	N2	N2
Dystric Histosols	(Od)	N2	N2	N2
Gelic Histosols	(Ox)	N2	N2	N2

Table 2.4 SOIL SUITABILITY RATINGS FOR LABLAB

Soil Unit		Low	Int.	High
Gleysols	(G)	N2	N2	N2
Eutric Gleysols	(Ge)	N2	N2	N2
Calcaric Gleysols	(Gc)	N2	N2	N2
Dystric Gleysols	(Gd)	N2	N2	N2
Mollic Gleysols	(Gm)	N2	N2	N2
Humic Gleysols	(Gh)	N2	N2	N2
Plinthic Gleysols	(Gp)	N2	N2	N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S1/S2	S1/S2	S1/S2
Dystric Regosols	(Rd)	S2	S2	S1/S2
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	N2	N2	N2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	N2	N2	N2
Rankers	(U)	N2	N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	N2	N2	N2
Orthic Solonchaks	(Zo)	N2	N2	N2
Mollic Solonchaks	(Zm)	N2	N2	N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	N2	N2	N2
Orthic Solonetz	(So)	N2	N2	N2
Mollic Solonetz	(Sm)	N2	N2	N2
Gleyic Solonetz	(Sg)	N2	N2	N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	N2	N2	N2
Haplic Yermosols	(Yh)	N2	N2	N2
Calcic Yermosols	(Yc)	N2	N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	N2	N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S1/S2	S1/S2	S1/S2
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S1/S2	S1/S2	S1/S2
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S1/S2	S1/S2	S1/S2
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S1/S2	S1/S2	S1/S2
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	S1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S2	S2	S1/S2
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S1/S2	S1/S2	S1/S2
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S2	S2	S2
Ferralic Cambisol	(Bf)	S2/N2	S2/N2	S2/N2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S1/S2	S1/S2	S1/S2

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S2	S2	S2
Ferric Luvisols	(Lf)	S2/N2	S2/N2	S2/N2
Albic Luvisols	(La)	N2	N2	N2
Plinthic Luvisols	(Lp)	N	N2	N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S2	S1/S2	S1
Eutric Podzoluvisols	(De)	S2	S1/S2	S1
Dystric Podzoluvisols	(Dd)	S2	S2	S2
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	N2	N2	N2
Orthic Podzols	(Po)	N2	N2	N2
Leptic Podzols	(Pl)	N2	N2	N2
Ferric Podzols	(Pf)	N2	N2	N2
Humic Podzols	(Ph)	N2	N2	N2
Placic Podzols	(Pp)	N2	N2	N2
Gleyic Podzols	(Pg)	N2	N2	N2
Planosols	(W)	S2	S2	S2
Eutric Planosols	(We)	S2	S2	S2
Dystric Planosols	(Wd)	S2	S2	S2
Mollic Planosols	(Wm)	S2	S2	S2
Humic Planosols	(Wh)	S2	S2	S2
Solodic Planosols	(Ws)	N2	N2	N2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2/N2	S2/N2	S2/N2
Orthic Acrisols	(Ao)	S2/N2	S2/N2	S2/N2
Ferric Acrisols	(Af)	S2/N2	S2/N2	S2/N2
Humic Acrisols	(Ah)	S2/N2	S2/N2	S2/N2
Plinthic Acrisols	(Ap)	N2	N2	N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S2	S2	S1/S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2/N2	S2/N2	S2/N2
Orthic Ferralsols	(Fo)	S2/N2	S2/N2	S2/N2
Xanthic Ferralsols	(Fx)	N2	N2	N2
Rhodic Ferralsols	(Fr)	S2	S2	S2
Humic Ferralsols	(Fh)	S2/N2	S2/N2	S2/N2
Acric Ferralsols	(Fa)	N2	N2	N2
Plinthic Ferralsols	(Fp)	N2	N2	N2
Histosols	(O)	N2	N2	N2
Eutric Histosols	(Oe)	N2	N2	N2
Dystric Histosols	(Od)	N2	N2	N2
Gelic Histosols	(Ox)	N2	N2	N2

Table 2.5 SOIL SUITABILITY RATINGS FOR SIRATRO

Soil Unit		Low	Int.	High
Gleysols	(G)	S2/N2	S2/N2	S2/N2
Eutric Gleysols	(Ge)	S2/N2	S2/N2	S2/N2
Calcaric Gleysols	(Gc)	N2	N2	N2
Dystric Gleysols	(Gd)	S2/N2	S2/N2	S2/N2
Mollic Gleysols	(Gm)	S2/N2	S2/N2	S2/N2
Humic Gleysols	(Gh)	S2/N2	S2/N2	S2/N2
Plinthic Gleysols	(Gp)	N2	N2	N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S2/N2	S2/N2	S2/N2
Dystric Regosols	(Rd)	S1/S2	S1/S2	S1
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	S2/N2	S2/N2	S2/N2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	N2	N2	N2
Rankers	(U)	S2/N2	S2/N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	N2	N2	N2
Orthic Solonchaks	(Zo)	N2	N2	N2
Mollic Solonchaks	(Zm)	N2	N2	N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	N2	N2	N2
Orthic Solonetz	(So)	N2	N2	N2
Mollic Solonetz	(Sm)	N2	N2	N2
Gleyic Solonetz	(Sg)	N2	N2	N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	N2	N2	N2
Haplic Yermosols	(Yh)	N2	N2	N2
Calcic Yermosols	(Yc)	N2	N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	N2	N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S2/N2	S2/N2	S2/N2
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S2/N2	S2/N2	S2/N2
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S2/N2	S2/N2	S2/N2
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S2/N2	S2/N2	S2/N2
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	S1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S1/S2	S1/S2	S1
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S2/N2	S2/N2	S2/N2
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S2	S2	S2
Ferralic Cambisol	(Bf)	S2	S2	S2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S2/N2	S2/N2	S2/N2

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S2	S2	S2
Ferric Luvisols	(Lf)	S2	S2	S2
Albic Luvisols	(La)	S2	S2	S2
Plinthic Luvisols	(Lp)	S2/N2	S2/N2	S2/N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S2	S1/S2	S1
Eutric Podzoluvisols	(De)	S2	S1/S2	S1
Dystric Podzoluvisols	(Dd)	S2	S2	S1/S2
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	N2	N2	N2
Orthic Podzols	(Po)	N2	N2	N2
Leptic Podzols	(Pl)	N2	N2	N2
Ferric Podzols	(Pf)	N2	N2	N2
Humic Podzols	(Ph)	N2	N2	N2
Placic Podzols	(Pp)	N2	N2	N2
Gleyic Podzols	(Pg)	N2	N2	N2
Planosols	(W)	S2	S2	S2
Eutric Planosols	(We)	S2	S2	S2
Dystric Planosols	(Wd)	S2	S2	S2
Mollic Planosols	(Wm)	S2	S2	S2
Humic Planosols	(Wh)	S2	S2	S2
Solodic Planosols	(Ws)	N2	N2	N2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2	S1/S2	S1
Orthic Acrisols	(Ao)	S2	S1/S2	S1
Ferric Acrisols	(Af)	S2	S1/S2	S1
Humic Acrisols	(Ah)	S2	S1/S2	S1
Plinthic Acrisols	(Ap)	S2/N2	S2/N2	S2/N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S1/S2	S1/S2	S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2	S2	S2
Orthic Ferralsols	(Fo)	S2	S2	S2
Xanthic Ferralsols	(Fx)	S2/N2	S2/N2	S2/N2
Rhodic Ferralsols	(Fr)	S2	S2	S2
Humic Ferralsols	(Fh)	S2	S2	S2
Acric Ferralsols	(Fa)	S2/N2	S2/N2	S2/N2
Plinthic Ferralsols	(Fp)	S2/N2	S2/N2	S2/N2
Histosols	(O)	N2	N2	N2
Eutric Histosols	(Oe)	N2	N2	N2
Dystric Histosols	(Od)	N2	N2	N2
Gelic Histosols	(Ox)	N2	N2	N2

Table 2.6 SOIL SUITABILITY RATINGS FOR FORAGE VIGNA

Soil Unit		Low	Int.	High
Gleysols	(G)	N2	N2	N2
Eutric Gleysols	(Ge)	N2	N2	N2
Calcaric Gleysols	(Gc)	N2	N2	N2
Dystric Gleysols	(Gd)	N2	N2	N2
Mollic Gleysols	(Gm)	N2	N2	N2
Humic Gleysols	(Gh)	N2	N2	N2
Plinthic Gleysols	(Gp)	N2	N2	N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S2	S2	S2
Dystric Regosols	(Rd)	S2	S1/S2	S1
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	S2	S2	S2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	N2	N2	N2
Rankers	(U)	N2	N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	N2	N2	N2
Orthic Solonchaks	(Zo)	N2	N2	N2
Mollic Solonchaks	(Zm)	N2	N2	N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	N2	N2	N2
Orthic Solonetz	(So)	N2	N2	N2
Mollic Solonetz	(Sm)	N2	N2	N2
Gleyic Solonetz	(Sg)	N2	N2	N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	N2	N2	N2
Haplic Yermosols	(Yh)	N2	N2	N2
Calcic Yermosols	(Yc)	N2	N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	N2	N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S2	S2	S2
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S2	S2	S2
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S2	S2	S2
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S2	S2	S2
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	S1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S2	S1/S2	S1
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S2	S2	S2
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S2	S2	S2
Ferralic Cambisol	(Bf)	S2	S2	S2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S2	S2	S2

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S2	S2	S2
Ferric Luvisols	(Lf)	S2	S2	S2
Albic Luvisols	(La)	S2	S2	S2
Plinthic Luvisols	(Lp)	S2/N2	S2/N2	S2/N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S2	S1/S2	S1
Eutric Podzoluvisols	(De)	S2	S1/S2	S1
Dystric Podzoluvisols	(Dd)	S2	S2	S1/S2
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	N2	N2	N2
Orthic Podzols	(Po)	N2	N2	N2
Leptic Podzols	(Pl)	N2	N2	N2
Ferric Podzols	(Pf)	N2	N2	N2
Humic Podzols	(Ph)	N2	N2	N2
Placic Podzols	(Pp)	N2	N2	N2
Gleyic Podzols	(Pg)	N2	N2	N2
Planosols	(W)	S2	S2	S2
Eutric Planosols	(We)	S2	S2	S2
Dystric Planosols	(Wd)	S2	S2	S2
Mollic Planosols	(Wm)	S2	S2	S2
Humic Planosols	(Wh)	S2	S2	S2
Solodic Planosols	(Ws)	N2	N2	N2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2	S1/S2	S1
Orthic Acrisols	(Ao)	S2	S1/S2	S1
Ferric Acrisols	(Af)	S2	S1/S2	S1
Humic Acrisols	(Ah)	S2	S1/S2	S1
Plinthic Acrisols	(Ap)	S2/N2	S2/N2	S2/N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S2	S1/S2	S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2	S2	S2
Orthic Ferralsols	(Fo)	S2	S2	S2
Xanthic Ferralsols	(Fx)	S2/N2	S2/N2	S2/N2
Rhodic Ferralsols	(Fr)	S2	S2	S2
Humic Ferralsols	(Fh)	S2	S2	S2
Acric Ferralsols	(Fa)	S2/N2	S2/N2	S2/N2
Plinthic Ferralsols	(Fp)	S2/N2	S2/N2	S2/N2
Histosols	(O)	N2	N2	N2
Eutric Histosols	(Oe)	N2	N2	N2
Dystric Histosols	(Od)	N2	N2	N2
Gelic Histosols	(Ox)	N2	N2	N2

Table 2.7 **SOIL SUITABILITY RATINGS FOR SOWN GRASS**

Soil Unit		Low	Int.	High
Gleysols	(G)	S1	S1	S1
Eutric Gleysols	(Ge)	S1	S1	S1
Calcaric Gleysols	(Gc)	S1	S1	S1
Dystric Gleysols	(Gd)	S2	S1/S2	S1
Mollic Gleysols	(Gm)	S1	S1	S1
Humic Gleysols	(Gh)	S1	S1	S1
Plinthic Gleysols	(Gp)	S2/N2	S2/N2	S2/N2
Gelic Gleysols	(Gx)	N2	N2	N2
Regosols	(R)	S1	S1	S1
Eutric Regosols	(Re)	S1	S1	S1
Calcaric Regosols	(Rc)	S1	S1	S1
Dystric Regosols	(Rd)	S2	S1/S2	S1
Gelic Regosols	(Rx)	N2	N2	N2
Lithosols	(I)	N2	N2	N2
Arenosols	(Q)	S2	S2	S2
Cambic Arenosols	(Qc)	S2	S2	S2
Luvic Arenosols	(Ql)	S2	S2	S2
Ferralic Arenosols	(Qf)	S2/N2	S2/N2	S2
Albic Arenosols	(Qa)	N2	N2	N2
Rendzinas	(E)	S2	S2/N2	N2
Rankers	(U)	S2	S2/N2	N2
Andosols	(T)	S1	S1	S1
Ochric Andosols	(To)	S1	S1	S1
Mollic Andosols	(Tm)	S1	S1	S1
Humic Andosols	(Th)	S1	S1	S1
Vitric Andosols	(Tv)	N2	N2	N2
Vertisols	(V)	S2/N2	S1S2N2	S1
Pellic Vertisols	(VP)	S2/N2	S1S2N2	S1
Chromic Vertisols	(Vc)	S2/N2	S1S2N2	S1
Solonchaks	(Z)	N2	N2	N2
Orthic Solonchaks	(Zo)	N2	N2	N2
Mollic Solonchaks	(Zm)	S2/N2	S2/N2	S2/N2
Takyric Solonchaks	(Zt)	N2	N2	N2
Gleyic Solonchak	(Zg)	N2	N2	N2
Solonetz	(S)	S2	S2	S2
Orthic Solonetz	(So)	S2	S2	S2
Mollic Solonetz	(Sm)	S2	S2	S2
Gleyic Solonetz	(Sg)	S2/N2	S2/N2	S2/N2

Soil Unit		Low	Int.	High
Yermosols	(Y)	S2/N2	S2/N2	N2
Haplic Yermosols	(Yh)	S2/N2	S2/N2	N2
Calcic Yermosols	(Yc)	S2/N2	S2/N2	N2
Gypsic Yermosols	(Yy)	N2	N2	N2
Luvic Yermosols	(Yl)	S2/N2	S2/N2	N2
Takyric Yermosols	(Yt)	N2	N2	N2
Xerosols	(X)	S1	S1	S1
Haplic Xerosols	(Xh)	S1	S1	S1
Calcaric Xerosols	(Xk)	S1	S1	S1
Gypsic Xerosols	(Xy)	N2	N2	N2
Luvic Xerosols	(Xl)	S1	S1	S1
Kastanozems	(K)	S1	S1	S1
Haplic Kastanozems	(Kh)	S1	S1	S1
Calcic Kastanozems	(Kk)	S1	S1	S1
Luvic Kastanozems	(Kl)	S1	S1	S1
Chernozems	(C)	S1	S1	S1
Haplic Chernozems	(Ch)	S1	S1	S1
Calcic Chernozems	(Ck)	S1	S1	S1
Luvic Chernozems	(Cl)	S1	S1	S1
Glossic Chernozems	(Cg)	S1	S1	S1
Phaeozems	(H)	S1	S1	S1
Haplic Phaeozems	(Hh)	S1	S1	S1
Calcaric Phaeozems	(Hc)	S1	S1	S1
Luvic Phaeozems	(Hl)	S1	S1	S1
Gleyic Phaeozems	(Hg)	S1S2N2	S1S2N2	S1S2N2
Greyzems	(M)	S1	S1	S1
Orthic Greyzems	(Mo)	S1	S1	S1
Gleyic Greyzems	(Mg)	S1S2N2	S1S2N2	S1S2N2
Cambisols	(B)	S1	S1	S1
Eutric Cambisols	(Be)	S1	S1	S1
Dystric Cambisols	(Bd)	S2	S1/S2	S1
Humic Cambisols	(Bh)	S1	S1	S1
Gleyic Cambisols	(Bg)	S1	S1	S1
Gelic Cambisols	(Bx)	N2	N2	N2
Calcic Cambisols	(Bk)	S1	S1	S1
Chromic Cambisols	(Bc)	S1	S1	S1
Vertic Cambisols	(Bv)	S1	S1	S1
Ferralic Cambisol	(Bf)	S2	S2	S1/S2
Luvisols	(L)	S1	S1	S1
Orthic Luvisols	(Lo)	S1	S1	S1
Chromic Luvisols	(Lc)	S1	S1	S1
Calcic Luvisols	(Lk)	S1	S1	S1

Soil Unit		Low	Int.	High
Vertic Luvisols	(Lv)	S1	S1	S1
Ferric Luvisols	(Lf)	S2	S2	S2
Albic Luvisols	(La)	S2	S2	S2
Plinthic Luvisols	(Lp)	S2/N2	S2/N2	S2/N2
Gleyic Luvisols	(Lg)	S1S2N2	S1S2N2	S1S2N2
Podzoluvisols	(D)	S1	S1	S1
Eutric Podzoluvisols	(De)	S1	S1	S1
Dystric Podzoluvisols	(Dd)	S2	S2/S1	S1
Gleyic Podzoluvisols	(Dg)	S1S2N2	S1S2N2	S1S2N2
Podzols	(P)	S2	S2	S2
Orthic Podzols	(Po)	S2	S2	S2
Leptic Podzols	(Pl)	S2	S2	S2
Ferric Podzols	(Pf)	S2/N2	S2/N2	S2/N2
Humic Podzols	(Ph)	S2	S2	S2
Placic Podzols	(Pp)	S2	S2	S2
Gleyic Podzols	(Pg)	S2/N2	S2/N2	S2/N2
Planosols	(W)	S2	S2	S1/S2
Eutric Planosols	(We)	S2	S2	S1/S2
Dystric Planosols	(Wd)	S2	S2	S1/S2
Mollic Planosols	(Wm)	S2	S2	S1/S2
Humic Planosols	(Wh)	S2	S2	S1/S2
Solodic Planosols	(Ws)	S2/N2	S2/N2	S2
Gelic Planosols	(Wx)	N2	N2	N2
Acrisols	(A)	S2	S2	S1/S2
Orthic Acrisols	(Ao)	S2	S2	S1/S2
Ferric Acrisols	(Af)	S2/N2	S2/N2	S2/N2
Humic Acrisols	(Ah)	S2	S2	S1/S2
Plinthic Acrisols	(Ap)	S2/N2	S2/N2	S2/N2
Gleyic Acrisols	(Ag)	S2/N2	S2/N2	S2/N2
Nitosols	(N)	S1	S1	S1
Eutric Nitosols	(Ne)	S1	S1	S1
Dystric Nitosols	(Nd)	S2	S1/S2	S1
Humic Nitosols	(Nh)	S1	S1	S1
Ferralsols	(F)	S2	S2	S1/S2
Orthic Ferralsols	(Fo)	S2	S2	S1/S2
Xanthic Ferralsols	(Fx)	S2/N2	S2/N2	S2
Rhodic Ferralsols	(Fr)	S2	S2	S1/S2
Humic Ferralsols	(Fh)	S2	S2	S1/S2
Acric Ferralsols	(Fa)	S2/N2	S2/N2	S2/N2
Plinthic Ferralsols	(Fp)	S2/N2	S2/N2	S2/N2
Histosols	(O)	S1/S2	S1/S2	S1/S2
Eutric Histosols	(Oe)	S1/S2	S1/S2	S1/S2
Dystric Histosols	(Od)	S2	S2	S1/S2
Gelic Histosols	(Ox)	N2	N2	N2

Table 3.1 **SOIL PHASE SUITABILITY RATINGS**

	Verano Stylo			Chamaecrista			Centrosema			Lablab			Siratro			Forage vigna			Sown pasture		
	High	Int.	Low	High	Int.	Low	High	Int.	Low	High	Int.	Low	High	Int.	Low	High	Int.	Low	High	Int.	Low
Stony Phase	N2	S2N2	S2	N2	S2N2	S2	N2	S2N2	S2	N2	S2N2	S2N2	N2	S2N2	S2	N2	S2N2	S2N2	N2	S2N2	S2
Lithic Phase	N2	N2	S2N2	N2	N2	S2N2	N2	N2	S2N2	N2	N2	S2	N2	N2	S2N2	N2	N2	N2	N2	N2	S2N2
Petric Phase	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2
Petrocalcic Phase	N2	N2	N2	S2N2	S2N2	S2N2	S2N2	S2N2	S2N2	S2N2	S2N2	S2N2	N2	N2	N2	N2	N2	N2	S2N2	S2N2	S2N2
Petrogypsic Phase	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	S2N2	S2N2	S2N2
Petroferric Phase	S2N2	S2	S2	S2N2	S2	S2	S2N2	S2	S2	S2N2	S2N2	S2N2	S2N2	S2	S2	S2N2	S2N2	S2N2	S2N2	S2N2	S2N2
Phreatic Phase	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1	S1
Fragipan Phase	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S2	S2	S1S2	S1S2	S1S2	S1S2	S2	S2	S1S2	S1S2	S1S2
Duripan Phase	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S1S2	S2	S2	S1S2	S1S2	S1S2	S1S2	S2	S2	S1S2	S1S2	S1S2
Saline Phase	N2	N2	N2	N2	N2	N2	S2N2	S2N2	S2N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	S2N2	S2N2	S2N2
Sodic Phase	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	N2	S2N2	S2N2	S2N2

Table 4.1 EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF VERANO STYLO UNDER LOW, INTERMEDIATE AND HIGH LEVELS OF INPUTS AND TECHNOLOGY

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	187	2405	2761	2953	554	2264	2575	2912	1387	2545	1682	2692
Burkina Faso	362	2094	4540	15790	601	2395	4442	15348	1045	3765	3515	14464
Cameroon	338	8190	24156	11092	2030	9637	21545	10563	3843	11427	18378	10128
Chad	253	3259	10741	110871	736	5820	8724	109843	1669	10495	5286	107674
Cote d'Ivoire	580	6862	13015	8417	1600	7448	11464	8361	3094	7748	8947	9084
Gambia	0	25	454	518	0	187	292	518	0	401	110	486
Ghana	678	3840	9221	6563	1063	5339	7420	6480	2212	7537	3812	6740
Guinea	618	9754	2692	9776	793	9734	2600	9713	1832	9161	2148	9699
Guinea Bissau	136	1003	999	1364	143	1035	960	1364	416	1101	640	1346
Liberia	0	196	4157	6342	0	793	3560	6342	0	1390	2963	6342
Mali	89	2050	5684	114323	326	2314	5046	114459	762	3971	4102	113309
Mauritania	0	57	220	100757	0	155	123	100757	0	253	32	100749
Niger	0	81	4	116102	0	81	12	116094	0	81	34	116072
Nigeria	1871	19691	19264	42877	4467	19983	16971	42283	10429	21317	11205	40752
Senegal	60	841	3891	12051	77	1290	3463	12013	164	2719	2490	11470
Sierra Leone	0	1094	2137	3582	12	1186	2034	3582	23	1277	1929	3584
Togo	173	1706	1443	1639	411	1627	1325	1598	1094	1591	700	1577
West Africa	5344	63149	105379	565017	12813	71288	92556	562232	27970	86779	67970	556170
Anticipated Yield Range (t/ha consumable biomass)	3.0-2.4	2.4-1.2	1.2-0.6	0.6-0.0	7.5-6.0	6.0-2.7	3.0-1.5	1.5-0.0	11.9-9.5	9.5-4.8	4.8-2.4	2.4-0.0

Note: Extents do not include protected areas and human settlement areas

Table 4.2 **EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF CHAMAECRISTA UNDER LOW, INTERMEDIATE.AND HIGH LEVELS OF INPUTS AND TECHNOLOGY**

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	545	2050	2909	2801	739	2526	2542	2497	1268	2131	2192	2715
Burkina Faso	844	2622	6075	13246	1100	3054	6012	12621	1519	3687	5183	12397
Cameroon	429	5608	26406	11333	2049	9571	21622	10534	3444	11560	18805	9967
Chad	1256	6268	8223	109377	1417	7449	7986	108272	2403	10857	5973	105892
Cote d'Ivoire	0	1565	16530	10780	1747	7982	11262	7883	3034	10408	7488	7944
Gambia	0	187	292	518	0	187	292	518	0	354	130	513
Ghana	497	2621	9289	7896	1325	5568	7143	6265	1830	7182	4409	6881
Guinea	809	2384	9604	10044	2284	7828	2943	9786	3502	7131	2431	9777
Guinea Bissau	286	1751	137	1327	286	1751	137	1327	301	1768	106	1327
Liberia	0	415	3938	6342	0	930	3560	6205	0	1664	2963	6068
Mali	399	3121	6419	112206	727	3191	6029	112198	1293	3049	5740	112062
Mauritania	0	171	334	100530	0	175	252	100608	0	290	84	100660
Niger	0	89	175	115923	0	95	189	115903	0	103	201	115883
Nigeria	1974	17098	24815	39816	5807	22341	18519	37036	9153	22937	15479	36134
Senegal	131	1624	4610	10478	155	1691	4703	10294	183	2354	4343	9962
Sierra Leone	0	131	2793	3890	12	993	2171	3637	23	1085	2067	3638
Togo	167	770	1776	2248	431	1468	1405	1658	670	1421	1096	1774
West Africa	7336	48475	124326	558752	18079	76799	96768	547242	28623	87981	78689	543596
Anticipated Yield Range (t/ha consumable Biomass)	2.7-2.2	2.2-1.1	1.1-0.6	0.6-0.0	6.8-5.4	5.4-2.7	2.7-1.4	1.4-0.0	10.9-8.7	8.7-4.4	4.4-2.2	2.2-0.0

Note: Extents do not include protected areas and human settlement areas

Table 4.3 **EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF CENTROSEMA UNDER LOW, INTERMEDIATE AND HIGH LEVELS OF INPUTS AND TECHNOLOGY**

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	295	3453	2226	2331	851	2937	2226	6014	1455	2397	1943	2510
Burkina Faso	659	2744	4315	15068	1100	3064	4740	13882	1463	3159	4109	14056
Cameroon	517	10620	22456	10183	2662	11447	20140	9528	4647	12224	17643	9262
Chad	475	5292	9117	110241	1417	7166	8132	108409	2403	9502	6988	106232
Cote d'Ivoire	692	8089	12536	7558	2958	9330	9808	6778	5224	9856	6452	7342
Gambia	0	25	533	440	0	192	382	423	0	354	208	435
Ghana	1013	4957	8934	5399	1635	6286	7066	5316	2292	7594	4240	6176
Guinea	1025	10950	1307	9559	2762	9306	1274	9498	4458	7653	1240	9489
Guinea Bissau	272	1737	174	1320	286	1754	142	1320	301	1770	111	1320
Liberia	0	196	5024	5476	0	930	4507	5258	0	1652	4002	5041
Mali	151	3183	4888	113924	727	2854	4719	113845	1293	2420	4791	113641
Mauritania	0	57	250	100727	0	155	180	100700	0	253	95	100686
Niger	0	81	23	116083	0	81	44	116062	0	81	44	116062
Nigeria	2831	27329	13806	39738	7787	24742	12998	38176	12318	22222	11461	37702
Senegal	120	1059	3932	11732	155	1559	3638	11492	183	1998	3473	11188
Sierra Leone	0	1947	1701	3165	23	2016	1609	3165	46	2084	1516	3167
Togo	267	2136	1224	1334	603	1878	1188	1292	973	1594	973	1421
West Africa	8315	83854	92444	554276	22966	85697	82791	547435	37056	86814	69288	545731
Anticipated Yield Range (t/ha consumable Biomass)	2.4-1.9	1.9-1.0	1.0-0.5	0.5-0.0	6.0-4.8	4.8-2.4	2.4-1.2	1.2-0.0	8.8-7.0	7.0-3.5	3.5-1.8	1.8-0.0

Note: Extents do not include protected areas and human settlement areas

Table 4.4 EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF LABLAB UNDER LOW, INTERMEDIATE AND HIGH LEVELS OF INPUTS AND TECHNOLOGY

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	208	1628	1383	5086	243	1625	1393	5045	696	1356	1182	5071
Burkina Faso	659	2085	1949	18094	813	2638	2027	17308	1232	2754	2097	16702
Cameroon	471	3579	8028	31697	700	3843	5738	33495	1448	4297	5330	32701
Chad	475	4142	7101	113406	601	5149	7145	112229	1587	7647	5498	110392
Cote d'Ivoire	227	1477	4657	22514	227	1371	3906	23370	314	1432	3346	23782
Gambia	0	25	397	575	0	30	397	571	0	192	240	565
Ghana	700	1704	3055	14842	777	1517	2408	15600	889	1471	2193	15749
Guinea	1023	3508	2809	15501	1075	3505	2884	15376	1086	3518	2342	15894
Guinea Bissau	272	865	116	2250	272	865	116	2250	286	882	84	2250
Liberia	0	52	338	10306	0	0	196	10499	0	0	415	10280
Mali	151	2112	2521	117360	162	2175	2641	117166	474	2201	2651	116818
Mauritania	0	57	215	100763	0	57	226	100751	0	155	135	100745
Niger	0	81	5	116101	0	81	14	116092	0	81	22	116084
Nigeria	1631	11112	13806	57155	1969	11555	13633	56546	3217	12102	11613	56772
Senegal	120	839	2531	13353	144	844	2607	13248	172	1371	2376	12924
Sierra Leone	0	12	910	5890	0	9	1118	5687	0	20	528	6265
Togo	135	670	1087	3069	151	702	1069	3038	259	747	806	3150
West Africa	6072	33949	50906	647962	7134	35967	47518	648270	11662	40227	40858	646142
Anticipated Yield Range (t/ha consumable Biomass)	2.8-2.2	2.2-1.1	1.1-0.6	0.6-0.0	7.0-5.6	5.6-2.8	2.8-1.4	1.4-0.0	11.0-8.8	8.8-4.4	4.4-2.2	2.2-0.0

Note: Extents do not include protected areas and human settlement areas

Table 4.5 **EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF SIRATRO UNDER LOW, INTERMEDIATE AND HIGH LEVELS OF INPUTS AND TECHNOLOGY**

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	770	2803	2367	2365	722	2538	2576	2469	1247	2149	2222	2687
Burkina Faso	946	2512	4003	15326	1100	2711	4252	14723	1519	3102	4109	14056
Cameroon	471	3579	8028	31697	1737	7492	18994	15553	2831	9320	17321	14304
Chad	1290	6148	7204	110481	1417	6966	7762	108979	2403	9502	6988	18892
Cote d'Ivoire	741	5659	10567	11906	1281	6338	10547	10709	2214	8509	8212	9939
Gambia	0	187	370	440	0	187	370	440	0	354	208	435
Ghana	850	3959	8239	7254	1137	4963	7087	7114	1539	6422	5081	7259
Guinea	1032	9677	2321	9810	2134	7528	3350	9828	3204	7127	2690	9819
Guinea Bissau	286	1754	142	1320	286	1754	142	1320	301	1770	111	1320
Liberia	0	256	1505	8935	0	325	1517	8853	0	545	1552	8598
Mali	462	3191	4718	113774	727	2846	4609	113963	1293	2420	4791	113641
Mauritania	0	155	125	100755	0	155	137	292	0	253	62	100719
Niger	0	81	8	116097	0	81	24	116081	0	81	41	116065
Nigeria	3820	23014	16181	40679	4582	21247	17733	40142	6967	23220	14901	38615
Senegal	131	1474	3337	11901	155	1457	3435	11796	183	1984	3257	11418
Sierra Leone	0	546	2569	3698	0	334	2727	3752	0	441	2628	3745
Togo	368	1475	1475	1642	330	1309	1542	1780	492	1400	1172	1897
West Africa	12253	70043	84030	572562	15608	68231	86805	568246	24193	78601	75346	560749
Anticipated Yield Range (t/ha consumable Biomass)	2.6-2.1	2.1-1.1	1.1-0.6	0.6-0.0	6.5-5.2	5.2-2.6	2.7-1.3	1.3-0.0	9.9-7.7	7.9-4.0	4.0-2.0	2.0-0.0

Note: Extents do not include protected areas and human settlement areas

Table 4.6 **EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF FORAGE VIGNA UNDER LOW, INTERMEDIATE AND HIGH LEVELS OF INPUTS AND TECHNOLOGY**

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of.Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	295	3355	1959	2696	851	2839	1959	2656	1455	2299	1943	2608
Burkina Faso	659	2688	3579	15861	1100	2984	3796	14906	1519	3101	4108	14058
Cameroon	517	10385	21536	11338	2662	11188	19266	10660	4647	12165	16856	10108
Chad	475	5060	9016	110574	1417	6924	7940	108843	2403	9422	7167	106133
Cote d'Ivoire	692	8035	11114	9034	2958	8861	8747	8303	5224	9687	6380	7583
Gambia	0	25	449	524	0	192	286	519	0	354	130	513
Ghana	1013	4773	7867	6649	1635	6093	6017	6558	2292	7392	4132	6485
Guinea	1025	10891	1267	9657	2762	9251	1235	9593	4458	7598	1200	9584
Guinea Bissau	272	1735	169	1327	286	1751	137	1327	301	1768	106	1327
Liberia	0	190	3113	7392	0	655	2734	7306	0	1271	2657	6767
Mali	151	2821	4173	115000	727	2629	4438	114351	1293	2408	4725	113719
Mauritania	0	57	212	100766	0	155	137	100743	0	253	62	100719
Niger	0	81	8	116097	0	81	24	116081	0	81	41	116065
Nigeria	2831	26397	12411	42064	7787	23922	11574	40421	12524	21212	10554	39413
Senegal	120	1021	3482	12220	155	1455	3234	11999	183	1982	3202	11476
Sierra Leone	0	1785	1641	3387	23	1854	1549	3387	46	1922	1458	3387
Togo	267	2112	1039	1544	603	1853	1002	1503	973	1570	966	1452
West Africa	8315	81410	83034	566130	22966	82688	74076	559160	37319	84486	65686	551399
Anticipated Yield Range (t/ha consumable Biomass)	1.7-1.4	1.4-0.7	0.7-0.4	0.4-0.0	4.2-3.4	3.4-1.7	1.7-0.9	0.9-0.0	6.7-5.4	5.4-2.7	2.7-1.4	1.4-0.0

Note: Extents do not include protected areas and human settlement areas

Table 4.7 EXTENTS (1000 ha) OF LAND VARIOUSLY SUITED TO RAINFED PRODUCTION OF SOWN PASTURE UNDER LOW, INTERMEDIATE AND HIGH LEVELS OF INPUTS AND TECHNOLOGY

Country	Low Level of Inputs and Technology				Intermediate Level of Inputs and Technology				High Level of Inputs and Technology			
	VS	S	MS	NS	VS	S	MS	NS	VS	S	MS	NS
Benin	316	2542	2507	2940	752	2537	2408	2609	1236	2345	2190	2534
Burkina Faso	412	2202	3565	16608	761	3058	3722	15246	1021	3611	3486	14669
Cameroon	908	19723	14948	8197	2793	20507	14073	6403	11473	19194	7796	5313
Chad	396	4128	9751	110849	926	7073	7896	109228	1479	10664	5184	107797
Cote d'Ivoire	1264	9721	6903	10985	1686	10577	6994	9617	4385	10070	5451	8969
Gambia	0	182	432	383	0	350	297	350	0	513	136	348
Ghana	1488	7082	4879	6853	1801	7548	5210	5743	3365	7328	4627	4983
Guinea	1078	8972	1485	11306	1361	10062	1663	9754	3969	7990	1216	9666
Guinea Bissau	138	948	925	1492	160	1081	980	1281	323	1113	786	1281
Liberia	330	1854	3280	5232	400	2156	3658	4481	668	3339	3716	2972
Mali	96	1848	4972	115228	307	2387	4722	114728	612	2695	4192	114646
Mauritania	0	57	218	100760	0	155	120	100760	0	253	22	100760
Niger	0	81	0	116106	0	81	28	116078	0	81	56	116049
Nigeria	5325	22838	14409	41131	8963	22290	14252	38198	13262	20172	12896	37372
Senegal	77	890	3326	12550	107	1490	3250	11996	124	2043	2978	11698
Sierra Leone	416	2795	1019	2582	528	2809	1087	2390	1605	2320	624	2265
Togo	296	1972	1099	1593	626	1911	1058	1366	1036	1640	994	1291
West Africa	12541	87835	73718	564795	21172	96071	71419	550226	44555	95371	56350	542613
Anticipated Yield Range (t/ha consumable Biomass)	3.2-2.6	2.6-1.3	1.3-0.7	0.7-0.0	7.9-6.3	6.3-3.2	3.2-1.6	1.6-0.0	12.9-10.2	10.2-5.1	5.1-2.6	2.6-0.0

Note: Extents do not include protected areas and human settlement areas

Table 5.1 SOIL AND TERRAIN CONSTRAINT RATINGS

TERRAIN SLOPE CONSTRAINTS

Severe Constraints:	All AEZ cells with 'c1' slopes (30-45%) and 'c2' slopes (> 45%)
Constraints:	All AEZ cells with 'b1' slopes (8-16%) and 'b2' slopes (16-30%)
Slight Constraints:	All AEZ cells with 'a2' slopes (2-8%)
No Constraints:	All AEZ cells with 'a1' slopes (0-2%)

SOIL DEPTH CONSTRAINTS

Severe Constraints:	All soils with depth limitations within 50 cm of the surface caused by the presence of coherent hardrock or hard-pans (Shallow soils): Lithosols (I), Renzinas (E), Rankers (U), all soils with Lithic phase
Constraints:	All soils with depth limitations within 100 cm of the surface by presence of Petrocalcic, Petrogypsic, Petroferric and Duripan phases.
No Constraints:	Deep soils: Other soils

NATURAL FERTILITY CONSTRAINTS

No Constraints:	Soils with high natural fertility: J, Je, G, Ge, Gc, Gm, R, Re, Rc, E, Tm, V, VP, Vc, Sm, Y, Yh, Yk, Yl, X, Xh, Xk, Xl, K, Kh, Kk, Kl, C, Ch, Ck, Cl, Cg, H, Hh, Hc, Hl, Hg, B, Be, Bk, Bv, L, Lo, Lk, Lv, Wm, N and Ne.
Constraints:	Soils with moderate natural fertility: Jd, Gh, Gd, Rd, Q, Qc, Ql, T, To, Th, Xy, M, Mo, Mg, Bc, Bd, Bh, Bg, Bf, Lf, Lp, Lc, Lg, D, De,Dg, Pl, W, We, Wh, A, Ao, Ah, Nd, Nh, Fr and Fh.
Severe Constraints:	Soils with low natural fertility and soils where a major land improvement is required before cultivation is possible: all other soils.

SOIL DRAINAGE CONSTRAINTS

Severe Constraints:	Poorly and imperfectly drained soils: All Gleysols (G, Ge, Gc, Gd, Gm, Gh, Gp and Gx), all Planosols (W, We, Wd, Wm, Wh, Ws, Wx) and all gleyic sub-groups (Zg, Sg, Mg, Hg, Lg, Dg, Pg and Ag), except Bg.
No Constraints:	Excessively and well drained soils: all other soils.

SOIL TEXTURE CONSTRAINTS

Severe Constraints:	Coarse textured soils. Soils with less than 18% clay, more than 65% sand, or have stones, boulders or rock outcrops in the surface layer or at the surface: All Arenosols (Q, Qc, Ql, Qf, Qa), all Regosols (R, Re, Rc, Rd, Rx) and Vitric Andosols (Tv) with texture "1", and all soils with petric and stony phase.
Constraints	Soils with heavy cracking clays: Soils with 30% or more clay to at least 50 cm deep, with cracks at least 1 cm wide and 50 cm deep at some period in most years (unless irrigated), and high bulk density between the cracks: All Vertisols (V, Vp, Vc) and vertic sub-groups (Bv and Lv)
No Constraints:	Soils with medium and fine textures: all other soils.

Table 5.1 CONTINUED

SOIL CHEMICAL CONSTRAINTS	
Severe Constraints:	Soils with severe salinity, sodicity, or gypsum limitations. (a) Soils with a high salt content or exchangeable sodium saturation within 100 cm of the surface: All Solonchaks (Z, Zo, Zm, Zt, Zg), all Solonetz (S, So, Sm, Sg) and Solodic Planosols (Ws). (b) Soils with gypsic horizons: Gypsic Xerosols (Xy), Gypsic Yermosols (Yy). (c) Soils with saline and sodic phases
No Constraints:	All other soils.
MICELLANEOUS UNITS	
The miscellaneous units of the SMW are considered as **Severe Constraints**, they include: Dunes, Shifting sands , Salt flats, Rock debris, Desert detritus and Glaciers and Snow caps	

APPENDIX 4

PRIMARY PRODUCTIVITY

Table 1.1 AVERAGE AGRO-CLIMATIC CROP PRODUCTIVITY

	Input Level	Length of Growing Period (days) 75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Pearl Millet	High	1.4	3.1	3.0	5.1	4.7	2.6	0.5	0.5	0.4	0.4	0.4
	Int.	0.9	2.0	2.1	3.6	3.3	1.9	0.4	0.4	0.3	0.3	0.3
	Low	0.4	0.8	1.0	1.7	1.4	1.1	0.3	0.2	0.2	0.2	0.2
Sorghum (lowland)	High	0.9	1.3	3.8	5.1	5.6	4.0	1.8	0.9	0.6	0.6	0.6
	Int.	0.5	1.4	2.5	3.7	4.1	2.7	1.3	0.6	0.4	0.4	0.4
	Low	0.2	0.4	0.8	1.7	1.9	1.2	0.5	0.2	0.2	0.2	0.2
Sorghum (highland)	High	0.1	0.5	1.5	2.8	3.7	4.1	3.3	2.3	1.6	1.0	1.0
	Int.	0.1	0.3	1.0	1.9	2.6	2.9	2.3	1.8	1.2	0.7	0.7
	Low	0	0.1	0.3	0.8	1.2	1.3	1.0	1.0	0.6	0.2	0.2
Maize (lowland)	High	0.9	2.3	5.4	7.1	7.9	7.3	5.8	4.1	3.6	3.2	2.7
	Int.	0.5	1.4	3.5	5.1	5.7	4.6	4.2	3.3	2.8	2.5	2.2
	Low	0.2	0.5	1.2	2.3	2.5	2.3	2.1	2.1	2.1	1.8	1.4
Maize (highland)	High	0.1	0.7	2.2	4.0	5.1	6.5	6.2	6.1	4.8	3.0	3.0
	Int.	0.1	0.4	1.4	2.8	3.6	4.7	4.5	4.7	3.8	2.1	2.1
	Low	0	0.2	0.5	1.2	1.6	2.1	2.1	2.4	2.1	1.0	1.0
Soybean	High	0.5	1.1	2.5	3.4	3.9	3.8	2.7	2.0	1.5	1.1	0.9
	Int.	0.3	0.7	1.8	2.4	2.7	2.6	2.1	1.5	1.1	1.1	0.4
	Low	0.1	0.3	0.7	0.9	0.9	1.0	1.1	0.7	0.4	0.1	0.1
Ph.bean (lowland)	High	0.5	1.1	2.5	3.4	3.9	3.8	2.7	2.0	1.5	1.1	0.9
	Int	0.3	0.7	1.7	2.4	2.7	2.5	1.8	1.2	0.9	0.7	0.4
	Low	0.1	0.3	0.7	1.0	0.9	0.9	0.6	0.4	0.4	0.1	0.1
Ph.bean (highland)	High	0.2	0.5	1.1	2.7	3.0	2.5	2.3	1.1	0.8	0.6	0.6
	Int	0.1	0.3	0.7	2.0	2.1	1.7	1.4	0.7	0.6	0.4	0.4
	Low	0.1	0.2	0.3	0.9	0.8	0.5	0.4	0.2	0.2	0.1	0.1

	Input Level	Length of Growing Period (days) 75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Sweet potato	High	0.9	2.1	4.5	10.1	10.1	11.1	13.1	11.1	5.2	5.1	3.5
	Int.	0.6	1.3	3.1	7.3	7.2	8.0	9.0	8.0	4.5	3.8	2.9
	Low	0.3	0.5	1.4	3.3	3.3	3.6	3.1	3.7	2.7	2.7	2.7
Cassava	High	0.3	0.6	1.5	3.5	8.8	10.9	11.9	12.4	13.2	7.4	7.4
	Int.	0.2	0.4	0.9	2.3	5.7	7.4	8.2	8.8	9.4	5.4	5.4
	Low	0.1	0.2	0.4	1.0	2.0	2.4	2.6	3.0	3.3	2.5	2.5
Rice (wetland)	High	0	0	0	2.0	2.9	3.9	3.9	3.9	6.7	6.7	6.7
	Int.	0	0	0	1.3	1.8	2.5	2.5	2.5	4.2	4.2	4.2
	Low	0	0	0	0.5	0.7	1.0	1.0	1.0	1.7	1.7	1.7
Spring wheat	High	0.2	0.9	2.5	4.3	5.6	4.0	2.3	0.8	0.7	0.7	0.7
	Int.	0.1	0.6	1.7	3.2	4.0	2.8	1.7	0.6	0.5	0.5	0.5
	Low	0.1	0.2	0.8	1.5	1.8	1.4	0.8	0.3	0.3	0.3	0.3
White potato	High	1.4	2.3	4.8	9.7	9.8	6.3	7.2	2.1	1.2	1.2	1.2
	Int	0.9	1.4	3.3	7.0	7.1	4.6	5.0	1.8	0.8	0.8	0.8
	Low	0.4	0.6	1.4	3.1	3.3	2.6	2.1	1.2	0.3	0.3	0.3
Rice (dryland)	High	0.3	0.8	1.1	1.6	2.6	4.4	7.1	7.1	7.2	5.8	5.1
	Int.	0.2	0.5	0.7	1.1	1.8	3.0	5.1	5.3	5.4	4.2	3.7
	Low	0.1	0.2	0.3	0.4	0.8	1.3	2.3	2.5	2.5	1.9	1.7
Cotton (lint)	High	0.0	0.1	0.6	1.1	1.1	0.6	0.5	0.3	0.2	0.1	0.1
	Int.	0.0	0.06	0.37	0.75	0.75	0.42	0.35	0.21	0.13	0.07	0.07
	Low	0.0	0.02	0.09	0.19	0.19	0.18	0.18	0.09	0.05	0.03	0.03
Groundnut	High	0.5	1.1	1.9	3.3	3.9	4.9	3.3	2.3	1.8	1.5	0.6
	Int.	0.3	0.7	1.3	2.4	2.8	3.3	2.3	1.6	1.2	1.1	0.4
	Low	0.1	0.3	0.6	1.1	1.3	1.0	1.0	0.7	0.4	0.4	0.2

Table 1.1 CONTINUED

	Input Level	75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Banana/Plantain	High	0	0	0	0	0	0.6	2.3	4.3	6.6	10.0	10.0
	Int.	0	0	0	0	0	0.4	1.4	2.7	4.1	6.3	6.3
	Low	0	0	0	0	0	0.2	0.6	1.1	1.7	2.5	2.5
Sugarcane	High	0	0.1	0.4	0.9	2.2	4.4	6.3	8.1	9.8	11.1	12.1
	Int.	0	0.1	0.2	0.6	1.4	2.8	4.0	5.1	6.1	6.9	7.6
	Low	0	0	0.1	0.2	0.6	1.1	1.6	2.0	2.4	2.8	3.0
Oilpalm	High	0	0	0	0	0	0.4	1.2	2.9	4.1	5.6	6.6
	Int.	0	0	0	0	0	0.3	0.8	1.8	2.6	3.5	4.2
	Low	0	0	0	0	0	0.1	0.3	0.7	1.1	1.4	1.7
Maiwa millet	High	0	0.6	1.5	2.4	3.4	3.1	1.6	0.7	0.5	0.5	0.3
	Int.	0	0.4	1.1	1.7	2.5	2.3	1.2	0.6	0.3	0.3	0.2
	Low	0	0.2	0.4	0.7	1.1	1.0	0.8	0.4	0.1	0.1	0.1
Sorghum[1] (lowland)	High	0	0.7	1.9	3.2	5.0	5.2	2.7	0.5	0.5	0.5	0.5
	Int.	0	0.5	1.3	2.2	3.7	3.8	2.1	0.4	0.4	0.4	0.4
	Low	0	0.2	0.6	1.0	1.7	1.7	1.2	0.2	0.2	0.2	0.2
Sorghum[1] (highland)	High	0	0.1	0.4	2.1	5.5	6.0	6.5	6.4	3.1	0.7	0.7
	Int.	0	0.1	0.3	1.4	4.0	4.5	4.7	4.6	2.0	0.5	0.5
	Low	0	0	0.1	0.6	1.8	2.2	2.1	1.4	0.5	0.2	0.2
Cowpea	High	0.5	1.2	2.2	2.8	3.2	3.0	3.1	3.7	3.9	4.3	1.7
	Int.	0.3	0.7	1.4	1.8	2.1	2.1	2.1	2.5	2.6	2.9	1.1
	Low	0.1	0.2	0.6	0.8	0.9	1.2	1.1	1.2	1.3	1.5	0.5
Verano stylo	High	0.1	0.8	2.2	6.4	9.5	11.9	11.1	9.5	7.2	6.0	6.0
	Int.	0.1	0.6	2.0	5.6	8.0	10.5	9.5	8.0	6.0	4.7	4.7
	Low	0.0	0.2	0.7	2.2	3.2	4.2	3.9	3.2	2.6	2.1	2.1

1 Photoperiodic cultivars

	Input Level	75-89	90-119	120-149	150-179	180-209	210-239	240-269	270-299	300-329	330-364	365
Chameacrista	High	0.4	1.1	4.2	6.7	8.9	10.9	8.1	8.1	5.7	5.7	5.7
	Int.	0.3	0.8	3.5	5.7	8.0	9.5	7.2	7.7	4.7	4.7	4.7
	Low	0.1	0.2	1.4	2.3	3.2	3.8	2.9	3.1	1.9	1.9	1.9
Centro	High	0.1	0.4	2.6	5.0	7.4	8.8	7.7	8.1	6.2	6.2	6.2
	Int.	0	0.3	2.3	5.1	7.0	8.4	7.1	8.1	5.2	5.2	5.2
	Low	0	0.1	0.9	2.0	2.8	3.3	2.8	3.2	2.1	2.1	2.1
Lablab	High	0.3	1.0	2.2	5.7	10.2	11.0	5.7	4.9	4.5	2.7	2.2
	Int.	0.3	0.8	1.9	4.7	9.4	9.8	4.2	4.0	3.1	2.0	1.8
	Low	0.1	0.3	0.8	1.9	3.8	3.9	1.7	1.3	1.2	0.8	0.7
Siratro	High	0.1	1.0	3.4	6.4	8.3	9.9	9.5	7.2	5.1	4.7	1.9
	Int.	0.1	0.7	2.8	5.7	7.7	9.1	6.8	6.1	4.3	3.6	1.1
	Low	0	0.3	1.1	2.3	3.1	3.6	2.7	2.5	1.7	1.5	0.4
Forage vigna	High	0.1	0.5	2.3	3.4	5.6	6.7	5.7	5.8	4.3	4.3	2.9
	Int.	0.0	0.3	1.7	3.0	4.9	5.8	4.8	5.4	3.5	3.5	2.1
	Low	0	0.1	0.7	1.1	2.0	2.3	1.9	2.2	1.4	1.4	0.9
Pasture, sown	High	0	0.2	2.1	6.7	10.3	12.7	12.7	12.7	12.7	9.5	9.5
	Int.	0	0.1	1.3	4.2	6.5	7.9	7.9	7.9	7.9	6.0	6.0
	Low	0	0	0.5	1.7	2.6	3.2	3.2	3.2	3.2	2.4	2.4
Pasture, natural	High	2.1	4.1	5.9	6.8	9.4	13.9	15.2	16.4	17.4	18.4	18.9
	Int.	1.4	2.3	3.3	3.9	5.4	8.0	8.7	9.4	10.0	10.5	10.8
	Low	0.7	0.8	1.2	1.4	2.0	2.9	3.2	3.4	3.6	3.8	3.9