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MANAGING A FRAGILE ECOSYSTEM FOR SUSTAINABLE AGRICULTURAL PRODUCTION

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ABSTRACT. The Intermediate Savannahs of Guyana are inhabited by resource poor farmers who lack physical and social infrastructural support. Added to this are problems of land tenure, credit and marketing and unfavourable agricultural policies. Farmers, therefore, are reluctant to adopt new technologies that demand high levels of resources.

The Intermediate Savannahs have about 59,000 ha of acid, nutrient deficient sandy soils that with expert management and appropriate technologies can provide good yields of cereals, grain legumes and pasture forages.

Research over the past twenty years coupled with experience from attempts at large agricultural enterprises indicate that a holistic and integrated approach to farming is necessary in such a fragile ecosystem.

The Caribbean Agricultural Research and Development Institute (CARDI) in collaboration with the Guyana National Agricultural Research Institute (NARI) has recommended improved technological packages or systems for crop and livestock production. Sustainablility indicators show that although the packages contain some technologically sound practices, other factors such as socio-economics and policies that are external to the Intermediate Savannahs are important. Further research in various priority technical areas is recommended so as to improve the sustainability aspects of the systems.

INTRODUCTION

The tropical humid Intermediate Savannahs (IS) of Guyana are located some 160 km behind the Atlantic coastal strip and occupy a land mass of approximately 270,000 ha. Of this, only about 80,000 ha are true savannahs that include close to 59,000 ha of acid sandy to loamy soils with reasonably good agricultural potential. However, these soils represent a fragile ecosystem that requires careful and expert management for the growing of crops and improved pastures (TAMS, 1976).

Native grasses of the IS have very low nutritive value and productivity, leading to poor liveweight gain of cattle, low stocking rates and as much as 5 - 8 years to prepare beef herd for market. Apart from the inherent soil problems of high acidity due to Al saturation, low nutrient content, high erosion potential, low moisture retention capacity, high compaction (especially in the Ultisols) and lack of irrigation, are the problems of developing cultivars tolerant to the prevailing acid conditions. Also, there are problems of the availability and utilization of inputs of labour and materials that are cost-efficient, developing a viable infrastructure, providing marketing and credit facilities, developing low-cost competitive and sustainable technologies that can induce farmers to adopt them, and the need to conserve resources in a very fragile ecosystem (IICA, 1991; World Res. Inst., 1990; Seré and Darío Estrada, 1983; Sánchez and Cochrane, 1989; Nicholaides, 1979; de Wet and Paul, 1992).

Agricultural activities that began in the IS during the 1940's have led to some successes as well as failures. These activities involved beef and dairy enterprises as well as the production of annual crops including maize (*Zea mays*), sorghum *(Sorghum bicolor)*, cowpea (*Vigna sinensis*), soybean *(Glycine max)*, cotton *(Gossypium barbadense)* and peanut (*Arachis hypogea)* (Smith et al., 1989). Lately, CARDI has developed innovative, appropriate and apparently sustainable technologies for integrated crop and livestock production using a systems approach.

Strategic management of the biophysical environment as well as economic and social parameters within integrated production systems appear to be critical for sustainable agricultural production in this complex ecosystem (MoAG/CARDI/OAS, 1997). Sustainable agriculture will depend on development and adoption of low-cosg9t technologies that are technically and economically suitable and whether in a scenario of increasing input costs, the savannahs can compete with areas closer to the market.

This paper examines the characteristics of the ecosystem and the nature of the production systems being recommended. It then attempts to draw conclusions as to the sustainablility of these systems against a background of sustainability indicators.

THE AGRO-SOCIOECONOMIC ENVIRONMENT

The Intermediate Savannahs are sparsely populated mainly because of physical isolation from the populated coastal strip of the country. At Ebini, the research station and a ranch operated by the Livestock Development Company (LIDCO) as a medium input forage-based cattle production system occupy about 4000 ha with over 3000 head of cattle. Forty families find employment at Ebini.

There is a 1000 ha privately owned mixed enterprise farm under cereals, legumes and fruit (mainly citrus) at Dubulay. Crops are rotated with improved pastures for cattle, sheep and buffalo (MoAG/CARDI/OAS, 1997).

Beef cattle ranches are found at Ituni and Eberoabo. The Guyana National Services established and still operates a small settlement at Kimbia where fields lay fallow after cotton and peanut enterprises failed in the mid 1980's. The small population there still cultivates plots of pigeon pea (*Cajanus cajan*), cowpea and peanut.

Commercial annual crop production (mainly soybean and maize) began in the Kibilibiri savannahs in 1970. After the project failed, some of the workers remained to grow smaller plots of peanut and cowpea and this has continued up to the present time.

Somewhat larger populations can be found in the townships at Ituni and Kwakwani from where trails radiate through the IS (Figure 1). During the wet seasons some of these trails are blocked by creek overflows.

In the past 15 to 20 years some pioneering small (about 20 ha) and medium-sized (20-200 ha) farmers have ventured inland away from their traditional slash and burn corn/food crop systems on the riverine soils and have adopted improved technologies for the cultivation of peanut and cowpea.

Altogether there are more than a dozen farming communities in the IS area with an estimated total popuation of 10,000 people who have skills mainly in cattle ranching, crop farming, logging and ecotourism activities but have remained poor (MoAG/CARDI/OAS. 1997; CARDI, 1997).

The supporting physical and social infrastructure for these communities include the Berbice river and its tributaries which are navigable by various types of vessels. The Berbice river itself is used by the cargo steamer that docks weekly at several wharves to move consumer goods and farmers' produce between the savannahs and the coastal port of New Amsterdam. Unpaved roads or trails lead to the IS from Linden via Ituni but some of these are impassable even by four-wheeled drive vehicles in the west season. These methods of transportation inflate the cost of inputs and outputs in the IS production process.

Although there are airstrips for light aircraft at Ebini, Kimbia, Dubulay and Kwakwani, public electricity and telephone communications are absent from smaller communities; private power generators and radios must be used in these areas.

Small schools, medical centres, churches and other social facilities are found in many of the IS settlements but staffing and supply levels are poor and maintenance costs are high. Domestic water is obtained from the many rivers and streams.

Farmers in the IS do not hold title to the lands they farm and this has prevented soil and water conservation and other farm infrastructure and agroforestry systems to be employed.

The marketing of the produce from the IS is mainly by way of the weekly river steamer. This imposes restrictions on harvesting, handling, storage and, quality of the end products. There is also no marketing agency operating in the IS; each farmer must make his/her own arrangements (CARDI, 1997).

Production in the IS can only be sustained if adequate financing and credit facilities are available especially during the early development stages. Technologies must be economically feasible before they can be adopted. But not many farmers in the IS have so far adopted the new integrated crop-livestock production systems. They have, however, adopted peanut and cowpea production systems but have run into marketing and labour availability problems (Small farmers group, 1996). Also, the availability and high cost of input materials for the production systems continue to hinder adoption. The National Agricultural Research Institute (NARI) and the Caribbean Agricultural Research and Development Institute (CARDI) both provide technical assistance to farmers in the IS.

In the IS it is critical that infrastructure is developed to support an adequate agro-socioeconomic environment. There is a need for conservation of the natural resource base on which sustainable agricultural systems depend. Technological development must be in sync with ecologial, edaphological and socio-economical limitations predominant in the particular ecosystem (Pineiro, 1989; Paul, 1992).

THE BIOPHYSICAL ENVIRONMENT

Topography:

The savannahs are gently undulating to flat plains with slopes of 1 to 8% and with altitudes from 6 to 10 m above sea level in the north to about 70 to 100 m above sea level in the southwest (FAO, 1965). The plains are dissected by many creeks and rivers (Figure 1), forming a regular dendrite drainage pattern. Because of the well-drained sandy soil the majority of the smaller creek beds are dry except after rains. Gullies vary from shallow to 10 - 15 m deep. The flat base of the deep gullies consists of a narrow strip of swamp or marshland on either side of the creeks.

Previous termite activity is manifested by their abandoned concrete-like nests that sometimes rise up to 2 m above the ground; these can disrupt land clearing operations (TAMS, 1976).

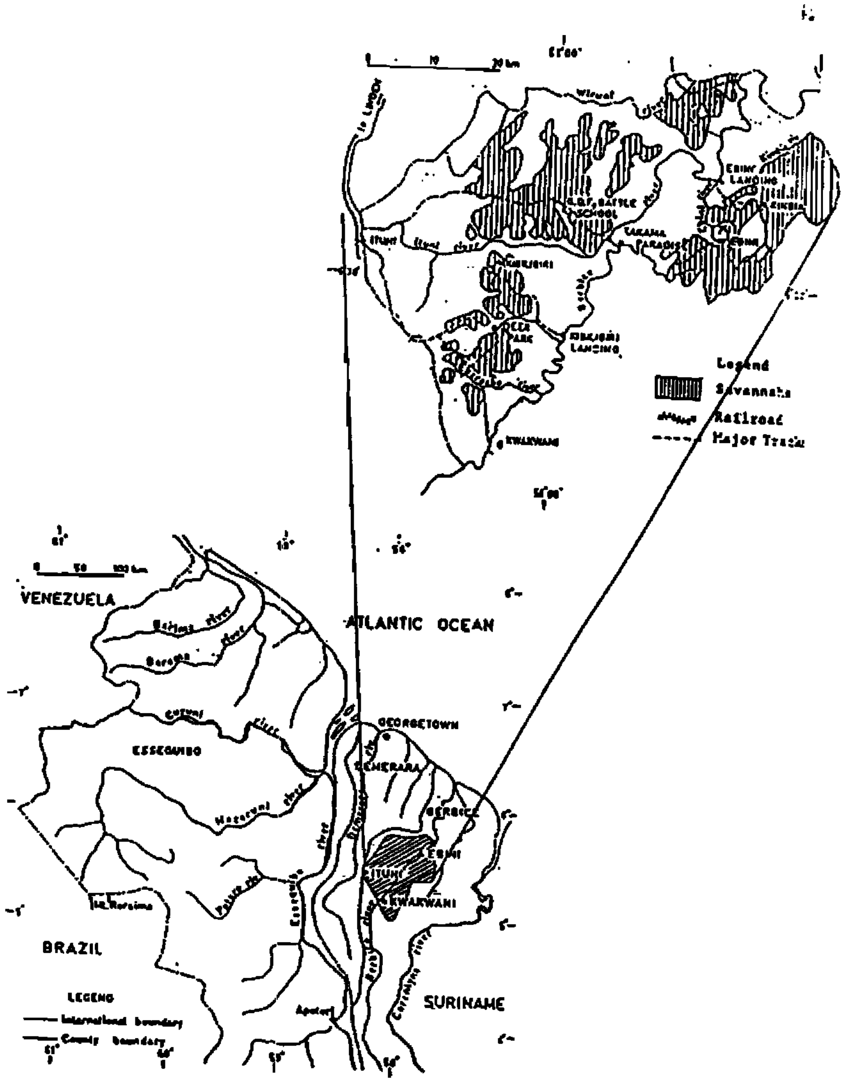


Figure 1. Map of Guyana showing the Intermediate Savannahs (Bullen, 1989).

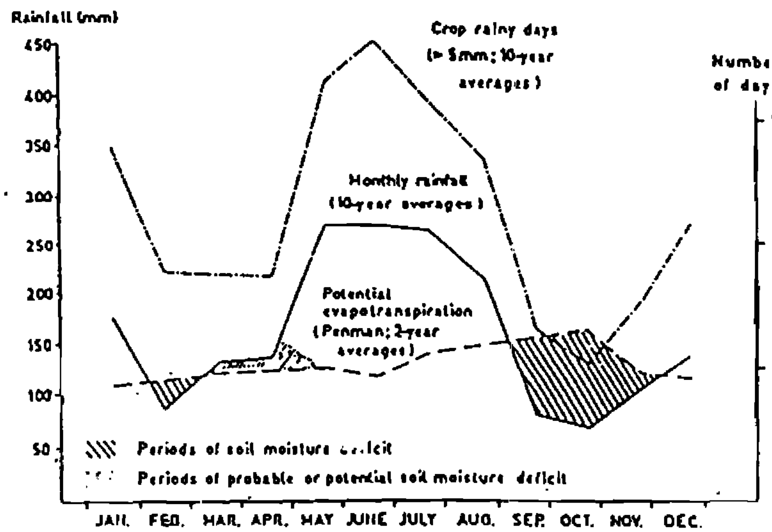
Climate:

The climate of the Intermediate Savannahs has been described as tropical wet and dry (TAMS, 1976). The mean annual rainfall is 2250 mm with a bimodal distribution pattern that allows two rainfed annual crops per year during April - August and November - January (Ahmad, 1989). Forty to 60 per cent of the rain falls in the longer wet season and about 16% in the shorter season. The frequent high rainfall intensities cause sheet, rill and gully erosion of the bare soil. Erosion commences with surprising speed where the natural vegetation is disturbed (TAMS, 1976). The high variability, intensity and erratic distribution of the monthly rainfall place constraints on agriculture (Simpson, 1989).

The mean annual temperature is 26°C with a maximum diurnal fluctuation of 10°C. Relative humidity is high in the early mornings (>90 per cent) with minimums in the early afternoons of 65 per cent. Average daily sunshine varies from 5 to 8 hours and cloud cover is pronounced during the rainy seasons; this causes a problem for late-maturing varieties of cereals (Mc Phearson, 1989; Seaton and Wickham, 1989; Simpson, 1989).

The average annual pan evaporation is 1830 mm with periods of soil moisture deficit in February and September to November (Figure 2).

Figure 2. Average monthly rainfall, potential evaporation and monthly number of crop rainy days at Ebini, Intermediate Savannahs, Guyana (TAMS, 1976)



Soils:

The soils of the Intermediate savannahs consist of sub-continental and old deltaic deposits of sands and clays with occurrences of bauxite, laterite and kaolinitic clay. The surface layer is characterized by white quartz sand (white sands) with brown loamy and sandy clay (Brown sands) sediments irregularly dispersed (TAMS, 1976). Thirty-eight soil types have been identified; they range in texture from coarse sands to medium sandy clays. The white sands are classified as Entisols and the brown sands as Utlisols and Oxisols (Ahmad, 1989).

The most extensively occurring soil types are the Ebini sandy loam, the Kasarama loamy sand, the Bukurana loamy sand, the Tabela sand and the very infertile Tiwiwid white sand which occurs in small pockets (TAMS, 1976). It has been recommended that the Tiwiwid sand should not be disturbed but left under its native vegetation because of its high erosivity when exposed (TAMS, 1976).

Physically, the soils are of good structure and are well-drained but they are low in clay and organic matter contents (Table 1). They possess low water-holding capacities and so are very droughty in the top layers during the dry season; clay and organic matter contents are critical to their agricultural potential. Tillage improves their physical condition but they crust easily, have a high erosive index and lose organic matter by oxidation very rapidly under the hot tropical climate (Simpson, 1989). The senior author (1997) has observed crop production on the soils over the last 3 cycles of cropping and is of the opinion that the management of the soils must be linked to increasing the level of organic matter by additions of crop residues and/or animal manure. This would serve to bind and retain clay particles and added nutrients within the soils and thereby improve their fertility and structure.

Chemically, the soils are acid (pH 4.3 to 5.9) with Al dominating the cation exchange complex. As a result, applied fertilizer P, considered to be the most limiting nutrient element in the soils, is rapidly fixed (Smith et al., 1989; Bullen, 1989). Soil acidity, especially in the subsoil, has been identified as a major limitation to root development (Ritchey et al., 1980; Foy et al., 1980).

Over the past several years, most of the research effort in the IS has concentrated on various aspects of soil fertility (Bullen et al., 1982; Bullen et al., 1983; Chesney 1973, 1975, 1979a, 1979b; Dookie, 1981; Downer, 1972; Fletcher, 1977, 1981).

For most crops, N, P, K, Ca and Mg are all limiting but micronutrients are also lacking. Dolomitic limestone is usually applied (incorporated to a depth of 20 - 30 cm) at the rate of 1 1/2 - 2 tons/ha after every 3 to 4 crop cycles to correct soil pH as well as to add Ca and Mg (Fletcher, 1989).

Flora and fauna:

The native flora of the ecosystem comprises about 70% forest and shrubs with 25% grassland vegetation in association with marsh and swamp plants (TAMS, 1976). On the fine and medium-textured soils there are forest tree species such as kautaballi (*Licania venosa*), greenheart (*Ocotea rodiaei)* and kabukalli (*Goupia glabra*). The most droughtly sandy soils have wallaba (*Eperva falcata*) and others. The true savannahs are dominated by the grasses *Andropogon* spp. and *Trachypogon plumosus* with scattered sand paper trees (*Curatella americana*). The palm marsh forest of the river levees contains mainly manicole (*Euterpe edulis)* and kokerite (*Maximiliana regia*). The swamp forest of the mineral - organic complexes and of the organic soils of the back swamps and creek valleys contains corkwood *(Pterocarpus officinalis)* and sarebebe (*Macrolobium* spp.). The small herbaceous swamps contain mainly razor grass sedge (*Scleria* and *Phyncospora* spp.).

Fauna typical of the area includes deer, land turtle and armadillo. Many species of fish live in the creeks and streams. Leaf cutting ants (*Atta* spp.) are found in most areas.

Water resources:

Six major tributaries of the Berbice river and their network of creeks and streams drain the area. These tributaries are Wiruni, Ituni, Kibilibiri, Eberoabo, Ebini and Wikki.

Because of the relatively flat relief and sandy soils, infiltration is rapid but excessive rains cause sheet flow which collects in depressions. Significant reservoir storage is not possible because of the low relief and the highly premeable soils. However, sub-surface storage produces dependable flows in surface channels and irrigation water can be obtained either by pumping from these channels (creeks and streams) or from wells placed adjacent to them. Groundwater can also be exploited from shallow wells 15 - 30 m deep. The existence of aquifers with a high water table indicates the probability of adequate water supplies for irrigation purposes (Ahmad, 1979). The quality of both surface and groundwater is good and the total supply is considered adequate to irrigate all the savannah lands in periods of critical shortage (TAMS, 1976).

Table 1. Chemical characteristics of the four dominant kinds of soil in the Intermediate Savannahs of Guyana (Simpson, 1989).

	Particle size				Org.			Exchange bases						Base	Truog
Depth	Sand	Silt	Clay	pH	C	Kjeld N	Exch acid	Ca	Mg	K	Na	Total	CEC	Sat.	P
cm	%				%		meq/100ml							%	ppm
Tiwiwid sand (Typic quartzipsamment; map unit 700)															
0-10	98	2	0	4.6	2.5	0.04	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0	6
10-17	98	2	0	4.5	1.7	0.02	0.2	0.0	0.0	0.0	0.1	0.1	0.3	33	6
17-36	98	2	0	5.4	0.1	0.01	0.0	0.0	0.0	0.0	0.0	0.0	0.0	100	7
36-86	97	3	0	5.8	0.0	0.00	0.0	0.0	0.0	0.0	0.1	0.1	0.1	100	9
86+	97	3	0	5.9	0.0	0.00	0.0	0.0	0.0	0.1	0.1	0.1	0.1	100	7
Tabela sand (Typic quartzipsamment; map unit 800)															
0-20	94	1	5	5.1	0.7	0.05	0.2	0.0	0.1	0.1	0.1	0.3	0.5	60	4
20-51	86	2	12	5.2	0.3	0.03	0.2	0.0	0.0	0.0	0.1	0.1	0.3	33	4
51-91	86	5	9	5.3	0.3	0.02	0.1	0.0	0.0	0.0	0.0	0.0	0.1	0	7
91-122	87	3	10	5.2	0.2	0.01	0.3	0.0	0.0	0.1	0.2	0.3	0.6	50	4
Kasarama loamy sand (Arenic paleudult; map unit 810)															
0-25	80	3	17	4.8	1.2	0.05	0.6	0.0	0.0	0.0	0.1	0.1	0.7	14	6
25-41	90	0	10	4.7	0.9	0.04	0.9	0.0	0.0	0.0	0.1	0.1	1.0	10	3
41-56	93	0	7	4.7	0.8	0.05	0.7	0.0	0.0	0.0	0.1	0.1	0.8	12	4
56-86	82	0	18	4.7	0.2	0.02	0.5	0.0	0.0	0.2	0.1	0.3	0.8	37	2
86-158	79	1	20	4.7	0.1	0.02	0.4	0.0	0.0	0.0	0.1	0.1	0.5	20	13
158-193	76	1	22	4.9	0.1	0.02	0.3	0.0	0.0	0.0	0.1	0.1	0.4	25	7
193+	65	4	31	5.0	0.3	0.02	0.3	0.0	0.0	0.0	0.1	0.1	0.4	24	0
Ebini sand loam (Typic paleudult; map unit 820)															
0-8	57	6	37	4.3	2.8	0.16	1.6	0.1	1.0	0.1	0.2	1.4	3.0	47	7
8-31	56	6	38	4.4	2.2	0.11	1.7	0.0	0.5	0.1	0.1	0.7	2.4	29	10
31-41	48	6	46	4.7	1.6	0.08	1.3	0.0	0.3	0.1	0.1	0.5	1.8	28	6
41-76	40	8	52	4.9	0.8	0.06	0.7	0.0	0.1	0.0	0.1	0.2	0.9	22	5
76-91	43	8	49	4.9	0.6	0.05	0.7	0.0	0.1	0.0	0.1	0.2	0.9	22	4
91-122	44	12	44	4.9	0.7	0.03	0.6	0.0	0.0	0.0	0.1	0.1	0.7	14	4

Land-use:

Detailed soil surveys have furnished precise soil data for planning the management and conservation of cultivated areas (TAMS,1976). The USDA Soil Classification system was used and the conclusion was that 60% of the acreage of the savannahs requires careful and expert management if crops or improved pastures are planted while 34% of the area (almost half of which is Tiwiwid white sand) has severe limitations and should not be cultivated under conventional technology.

In the 1940's cattle were driven from the Rupununi Savannahs in the south of Guyana (then, British Guiana) to the coastal market via the open grass Intermediate Savannahs which were considered an ideal intransit resting place for the animals prior to shipment down the Berbice river. But they lost weight, became unthrifty and lost a high percentage of their calves because of the low nutritional value of the native grasses. The Ebini livestock station was, therefore, established so as to improve the quality of the forage and upgrade the quality of the animals prior to marketing. However, soil nutrient problems soon emerged as a major constraint to productivity.

Bullen (1979) has described land use of the Intermediate Savannahs for livestock and crop production up to the 1970's. He stated that a sustained effort at livestock production on about 1540 ha at Ebini has had reasonable success over the years and that mineral deficiencies in soil and plant were recognized as limiting to cattle survival and beef production. Over the years, several pasture species have been introduced and established. Artificial fertilizers, limestone, crop residues and mineral supplemental feeds to the cattle have assisted the success.

Attempts at producing annual crops such as cowpea, peanut, soybean, cotton, corn, and sorghum on some 1730 ha in the Kimbia, Eberoabo and Kibilibiri savannahs under government-owned or supported commercial enterprises during the 1970's failed mainly because of climatic, soil and management problems (Fletcher, 1989).

The Dubulay Ranch has about 1000 ha under annual crops, orchards and pastures. Groups of small farmers have cultivated strips along waterways for the growing of grain legumes and pineapple (*Ananas comosus)* (TAMS,1976; CARDI, 1995).

Farming systems recommended for the intermediate savannahs:

The Caribbean Agricultural Research and Development Institute (CARDI) has been working for the past 15 years in collaboration with the Guyana National Agricultural Research Institute (NARI) and farmers of the IS in the development of low-cost sustainable technological packages for the ecozone. They have, therefore, recommended an integrated crop/livestock system, an annual cropping system, and an orchard system that are designed to conserve the natural resource base.

Integrated crop/livestock system:

Phase I - Intensive annual cropping: The first phase of pasture establishment is to grow annual row crops for 4 - 6 cycles (2 - 3 years). High yielding, acid and drought tolerant cultivars of annual cereal and grain legume crops have been selected over the last six years through germplasm introduction and evaluation.

During the month of June land is initially cleared, burned, and fertilized with 100 kg/ha N, 50 kg/ha P_2O_5, 25 kg/ha K (+25 kg/ha K at cultivation), 20 kg/ha Mg and 20 kg/ha S. Mo, Zn and Cu fertilizers are also applied. Limestone is applied at the rate of 1 - 2 tons/ha and disced in to a depth of about 15 cm. Soybean, cowpea, pigeon pea or peanut is drilled in strips alongside sorghum or maize. Pre-emergent herbicide is applied. Interrow cultivation is carried out 4 - 6 weeks after seedling emergence and insecticides are applied as necessary during the crop cycle. The grain legume is harvested in October and the cereal in November/December. The land is harrowed in January and a second cropping cycle takes place (Figure 3a).

After 4 - 6 cycles of cropping (annual applications of fertilizer are made) weed growth is generally heavy and the land is then planted to pasture in Phase II. The annual crops provide organic matter and nutrients to the soil as well as cash income towards the overall cost of pasture establishment. Nicholaides (1979) concluded that adequate cropping systems followed by pasture establishment make use of residual fertilization and appeared to be an economical and effective practice. This conclusion is shared by Mendez, the largest private farmer in the IS (Mendez, 1997).

Phase II - Sowing and establishment of pasture species and livestock production: The second phase of pasture establishment consists of having strips of cereal + grain legume alongside strips of grass + forage legumes (Figure [3bi]). This occurs during the last (4th - 6th) cycle of annual row cropping as stated in Phase I above.

Direct seeding of the pasture species is less labour intensive and enables faster establishment as compared to vegetative propagation.

A variation of Phase II (Figure [3bii]) can be carried out by planting the forage spp. as an understory to the cereal + grain legume intercrop 1 - 2 months prior to their harvest. The forage spp. then becomes established after the harvest of the annual crops.

About 6 months after establishment, the pasture is ready for grazing. A stocking rate of 1 animal per ha can be safely sustained throughout the year. Beef animals gain weight at a rate of 0.2 kg/head/day on fertilized native grass pastures (*Andropogon gayanus*) while on the improved mixed pastures as described above, they gain more than 0.4 kg/head/day (Wickham, 1996). This means that animals become marketable in 3 years as compared to 5 - 8 years on the unimproved native pastures.

Wickham (1996) has provided technical and economic data for forage-based cattle production systems in the IS during 1993 to 1996 (Table 2). He compared three systems of establishing the pastures, namely, system 1 with *Brachiaria humidicola* on virgin savannah, system 2 with row crop/pasture rotation as described above, and system 3 with *B. brizantha* mixed with the legume stylosanthes and planted on virgin savannah.

System 3 showed the highest production coefficient (0.5 kg/day). However, the rate of return on investment was lower than the other two systems because of the higher cost of production. Nevertheless, System 1 based on improved *Brachiaria bumidicola* pastures produced a 0.2 kg daily gain. These data compare favourably with weight gains reported for similar improved pastures in the Llanos Orientales of Colombia (CIAT, 1988). System 2 yielded the highest rate of return that might have been attributable to the build up of soil organic matter and fertility.

Table 2. Critical technical and economic data for forage-based cattle production systems in the Intermediate Savannahs during 1993-1996 (Wickham, 1996)

Variables	System 1	System2	System 3
Daily gain per annimal (kg)	0.2	0.3	0.5
Years to market	4	3	3.5
Cost per kg (US$)	0.9	0.7	1.0
Cost per ha (US$)	36	232	345
Internal rate of return (%)	18	21	16

System 1 Improved grass pastures (Brachiaria humidicola)
System 2 Row crop/pasture rotation
System 3 Mixed pastures (*B. humidicola* and *Stylosanthes spp.)*

The pasture establishment provides a permanent soil cover that minimizes soil erosion, increases soil organic matter content and controls weed proliferation while at the same time providing high quality forage for livestock.

Phase III - Rehabilitation of pastures: After the seventh year, that is, four to five years of pasture growth and grazing, the patures are generally degraded and need to be rehabilitated. This is done by ploughing under the pasture growth and establishing annual row crops once again as in Phase I (Figure 4).

Phase I

Years 1-3

Intensive annual crop production

Phase II

Years 4-6

Pasture establishment and livestock production

Phase III

Year 7

Rehabilitation of degrated pasture.
Return to intensive annual crop production

Figure 4. Summary of integrated crop/livestock system

Intensive annual crop production system:

Annual row crops recommended for the IS include sorghum, maize, soybean, peanut, pigeon pea, cowpea, cassava (*Manihot esculenta)* and cucurbits (*Citrullus spp.*). Over the last 10 years several cultivars of these crops have been screened for adaptation and high yield. The production practices for these crops are as described in Phase I in Section 4.1 above. Bullen (1996) has provided data on production and economic returns for selected row crops grown in the IS during 1995-96(Table 3).

Table 3. Production data and net economic returns for selected row crops grown in the Intermediate Savannahs during 1995-1996 (Bullen, 1996)

Variables	Soybean	Sorghum or maize	Peanut	Cowpea
Yield (kg/ha)	2500	3500	1500	1200
Production cost/ha (US$)	725	700	700	744
Net return/ha (US$)	50	140	480	108

It appears that a rotation of cereals and grain legumes is required for a sustainable cropping system. The legumes provide soil organic matter and nitrogen to the succeeding crop of cereals. This is particularly important in the poor sandy soils where fertilizer costs account for 16 - 31% of the total cost of production.

Orchard crop/row crop system:

Citrus (*Citrus* spp.), oil palm (*Elaeis guineensis*) and passion fruit (*Passiflora edulis*) are considered highly suitable for production. Other crops with moderate suitability include cashew (*Anacardium occidentale*) and carambola (*Averrhoa carambola*). Past farming experiences together with preliminary research observations at a large ranch in Dubulay and at the Ebini Crop Station have indicated that citrus fruit, especially orange and grapefruit, appear most suited for commercial production from a technological and marketing perspective. Frozen concentrate orange juice has a ready market in the USA while citrus pulp would serve as primary material for livestock feed.

Orchard cropping in the IS requires a number of prerequisites, namely:

- Establishment of nurseries with certified planting material and sound plant propagation technology.
- Adequate orchard management including irrigation, fertilization and insect and disease control.
- Annual crop production in the inter-rows to generate income during the early years of orchard establishment.
- Post harvest and processing facilities to ensure good quality of the end products.

The orchard crop/row crop system provides a permanent soil cover and increases soil organic matter. After the tree crops have developed their canopy, the row crops are replaced by pastures seeded understorey.

Small ruminants production system:

Sheep and goats are compatible with both row and orchard crop production systems. In a well-planned and managed system, sheep and goats would graze on cover crops established under citrus or other orchard crops as well as on crop residues and pastures established in rotation with row crops (Wickham, 1996).

Important factors to be considered for the successful operation of a sheep enterprise in the Intermediate Savannahs are:

(a) The size of unit should be about 500 ewes.
(b) The required area is 700 ha which should be under pastures, row crops and orchard crops.
(c) Finishing weight should be 30 kg (liveweight approximately 6 months from weaning)
(d) A lambing rate of 150 % with 2 breeding seasons per year and a lamb mortality no greater than 4 - 8 % (internal parasites to be controlled).

The breed recommended is the cross between local creole types and the Barbados Blackbelly. The Barbados Blackbelly increases the number of young while the creole types contribute to a more adapted animal that grows well under savannah conditions.

Currently, animals produced are absorbed by the local coastal market of Guyana where the demand exceeds supply.

Goat production parameters in the Intermediate Savannahs are similar to those for sheep. Possibilities exist for increased goat production; milk, cheese and hides can provide additional income (Wickham, 1997).

Sustainability of agricultural production in the intermediate savannahs:

Several researchers have indicated practices that are required for sustainability of agricultural production systems (Paul, 1992; Crosson and Rosenberg, 1989; Bullen, 1989; Reganold et al., 1990; CARDI,1995; Virmani et al., 1994; Beets, 1990; ICRAF, 1995; Hargrove, 1988). These practices include:

- Ecosystem characterization
- Conservation tillage
- Crop rotation
- Improved soil water relations through crop scheduling, irrigation and drainage
- Crop residue management
- Soil and water conservation
- Soil amelioration (liming, crop residue, animal manures, green manure)
- Contour cropping
- Rapid and persistent crop cover (soil not to be exposed to rainfall)
- Chemical and organic fertilizers
- Nutrient cycling
- Integrated pest management that reduces contamination of the environment by pesticides
- Improved farming systems to match soil, climate, animals and cultivars
- Organic matter enhancement and maintenance
- Legumes in cropping system
- Rhizobium and mycohirriza use
- Adapted high-yielding crop cultivars (tolerant to biotic and abiotic stresses)
- Cultivars efficient in nutrient and water use
- Pastures that resist overgrazing (persistent species)
- Use of renewable natural resources
- Holistic systems level management approach
- Agroforestry
- Appropriate land tenure
- Credit and marketing facilities and arrangements
- Supporting physical and social infrastructure
- National policies
- Cost-effective appropriate technology
- Technical assistance to producers
- Private sector participation

- Use of local inputs
- Increased social welfare
- Poverty alleviation
- User awareness of ecosystem degradative processes
- Farmer participation in technology development
- Survey of agro-socioeconomics of production systems in the ecozone

Bullen (1989) has examined climate, soil fertility, soil physical factors, weed growth, mechanization and other management considerations in past agricultural systems in the Intermediate Savannahs. The CARDI staff located in the IS have looked at present-day practices used by local farmers. They have also looked at the short-term sustainability of the production systems recommended in Section 4 above (CARDI, 1997). Their main conclusions are:

- High intensity rainfall reaching as much as 150 mm in 24 hours causes severe soil erosion and nutrient loss in the IS. Soil cover by crop or residue is of utmost importance. The recommended packages protect the soil.
- The high relative humidity is conducive to pests and diseases of crops. Integrated pest management (IPM) strategies are not used in the IS production systems; this is a serious drawback. In a scenario of increased cropping in the IS, there will be contamination of soil and surface and groundwater. Pesticide use must be reduced and research is needed to identify environmentally-friendly ones.
- Farmers do not employ adequate soil and water conservation methods such as contour cropping and reduced tillage, sheet, rill and gully erosion result. The systems will not be sustainable if these practices are not employed.
- Annual cropping systems now in use do not ensure adequate soil cover especially on the less clayey soils that are more predisposed to erosion. Intra and interrow spacing should be adequate and cultivars must rapidly develop a high leaf area index.
- Irrigation technology is not utilized due to its high cost of development and use. This means that in the dry season, forage quantity and quality are poor. The result is overgrazing and degradation of the pastures.
- Soil acidity in the subsoil affects root growth but lime placement is not deep enough to alleviate the problem. The quantity and placement of limestone needs investigation.
- Fertilizer application is not adequate to achieve high levels of production because the high cost of transport restricts use.
- Soils of the IS have a narrow range of moisture contents that allows their safe workability. The clayey soils compact and puddle easily. Appropriate tillage systems including zero tillage have not been worked out for the IS soils and have not been included as part of the recommended technological packages.
- Weed growth increases with cropping and severely reduces crop growth after about 4 to 6 cycles. Proper crop rotation systems are employed in the packages to deal with the problem.
- Scheduling of farm operations are extremely important with respect to weather, planting, crop maturity, harvesting, post-harvest handling, etc. These details have been worked out by the IS researchers and are part of the systems being transferred to farmers' fields.
- Crop improvement is required to provide cultivars that are efficient users of nutrients and

water and which are adapted to the biotic and abiotic stresses of the IS. Only a few cultivars have so far been selected and there is much work to be pursued in this area

- The ecosystem has not been adequately characterized so that the interactions between farming systems and environmental variables cannot be accurately predicted.
- Additions and maintenance of organic matter by crop residues and manures are critical to the sustainability of the soil resource base. The integrated crop/livestock system recommended for the IS is definitely a correct approach.
- Agroforestry is not practised in the IS because the local population obtains fuelwood, timber and other forest products from the forests that occupy the banks of watercourses. But the true savannahs are devoid of forests that can help tremendously to prevent soil erosion and restrict deforestation of the riverain areas.
- One of the greatest problems facing farmers in the IS is the lack of land ownership. Because of this, their land use approach is transient and not sustainable. Government must put in place a clear national strategy for land use as soon as possible or face the consequences of a degraded IS ecosystem.
- Attempts at establishing pastures without adequate liming, fertilizer applications and the interplanting of adapted legumes together with a lack of strict management systems have led to degraded pastures and poor carcass quality. An integrated approach to crop/livestock management ensures a sustainable production system.
- Unless physical and social infrastructures in the IS communities are drastically improved, agricultural production cannot be sustained and settlement cannot be encouraged. A good all weather road linking the IS with the bauxite mining town of Linden 30 km from Ituni would provide a transportation and communication miracle for the region and its inhabitants.
- The lack of firm markets for the products from the IS is a serious drawback to the transfer of improved agricultural technology and to increased production.
- The socio-economic feasibility of the production systems has not been assessed.

CONCLUSIONS

Innovative low-cost and apparently appropriate and sustainable technological packages have been developed for the commercialization of agriculture in the Intermediate Savannahs of Guyana. These packages contain several aspects that can lead to sustainable agricultural production. However, they lack many aspects that need to be investigated before their sustainability can be ascertained. Research is needed in the following priority areas:

(a) IPM strategies for crop and pasture production.
(b) Soil and water conservation methods including tillage methods.
(c) Crop cover of the soil by cropping systems that develop a rapid leaf area index.
(d) Irrigation of annual crops, pastures and orchard crops in the dry season and the effects on crop and animal productivity.
(e) Placement and quantity of limestone that needs to be added to the systems. Although component technology with limestone has been investigated in the past, there is a need to study the effect of liming the soil with the systems in place.
(f) Weed control within the systems and within an IPM approach.
(g) Crop improvement to provide species and cultivars that are adapted to the

environment and that are tolerant to biotic and abiotic stresses in the IS. As agriculture progresses in the region, these stresses such as diseases and pests are expected to increase. Varietal improvement is critical in this scenario. Seed production must accompany genetic improvement.

(h) Studies that characterize the ecosystem must proceed to understand the complex interaction among environmental variables as they change with agricultural activity. Geographical information systems must be employed to handle the huge amounts of data that must be generated.

(i) Agroforestry systems must be investigated because deforestation of the surrounding forests cannot proceed as at the present rate. Sustainable systems of logging are also required.

(j) Orchard establishment and management require urgent attention. Nurseries must be set up to fuel the drive towards fruit and tree crop production.

(k) The genetics, feeding and management of cattle, sheep and goats must receive attention within the crop/livestock systems if these systems are to be sustainable.

(l) Feed production from the annual crop outputs are an integral part of the crop/livestock systems. Work must be done on feed formulation and production in the IS itself; this would reduce feed imports into the area and generate employment.

(m) Socio-economic feasibility of the production systems need to be evaluated before their long-term sustainability can be determined.

Sustainability of the production packages obviously depend on the strategic management of the biophysical and agro-socioeconomical parameters within an integrated holistic approach. Annual crops provide early cash flow and sustained revenue while long term livestock/pasture and orchard systems ensure the viability of agroindustrial enterprises (MoAG/CARDI/OAS, 1997).

It is felt that sustainable agriculture on the acid soils must focus on practices that maintain the integrity of the fragile ecosystem. The developmental pathway depends on research that would provide crop varieties and new production systems which can efficiently utilize the natural resource base without degrading it.

But the sustainability of agricultural production in the IS perhaps depends on factors far removed from the Savannahs themselves. While technical and biophysical solutions can be employed *in situ* to maintain the ecosystem, political and economic factors linked to national agricultural policy dictate the land use and agricultural production practices employed in the area. Judging from the negative effects that these latter factors have had on past agricultural production ventures, it seems clear that they weigh heavily on the sustainability of future developments.

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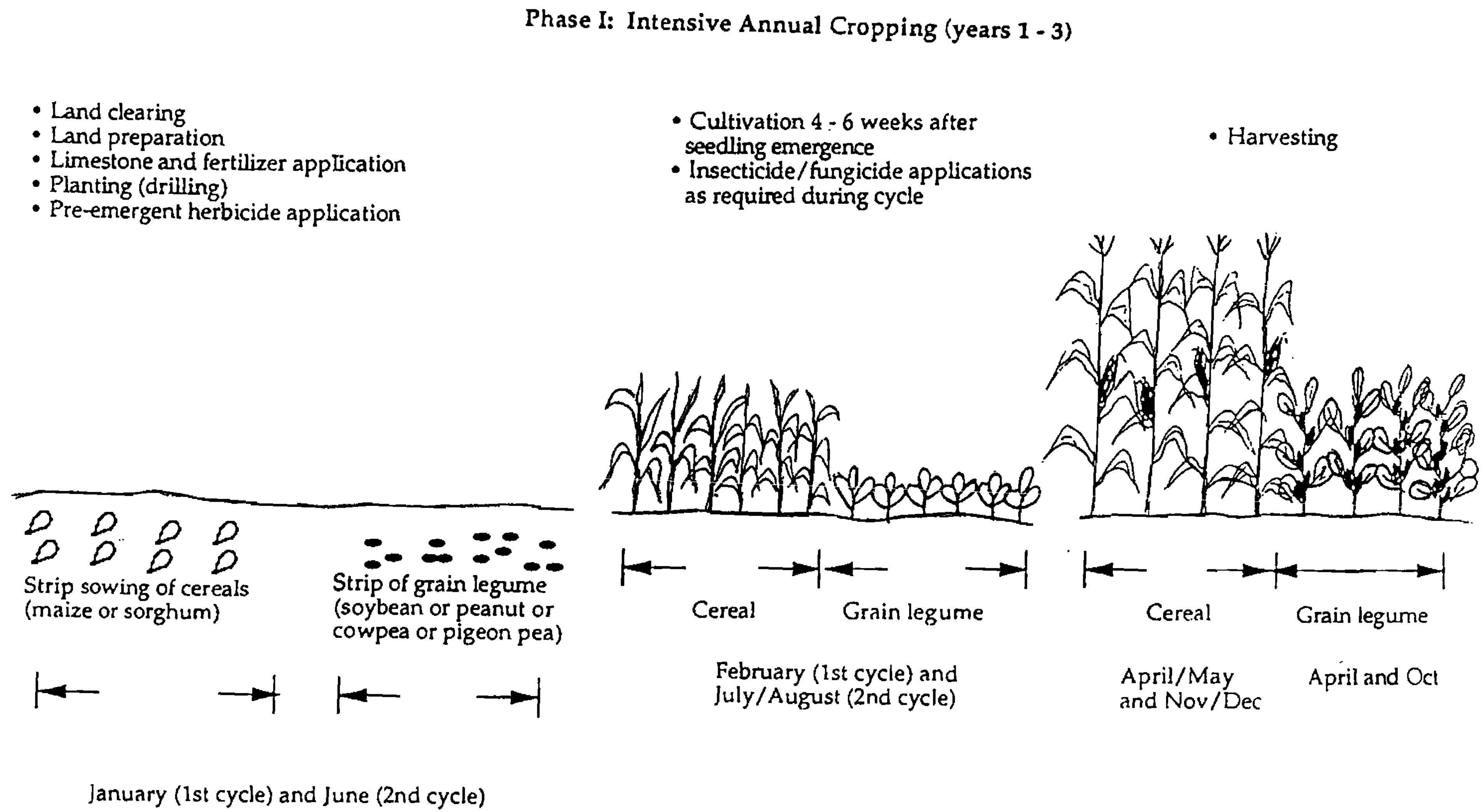


Figure 3a: Phase I of pasture establishment in the Intermediate Savannahs of Guyana (Wickham, 1996). Annual inter-crops for 4 - 6 cycles. There are 2 cycles per year, namely, January - May and June - November/December

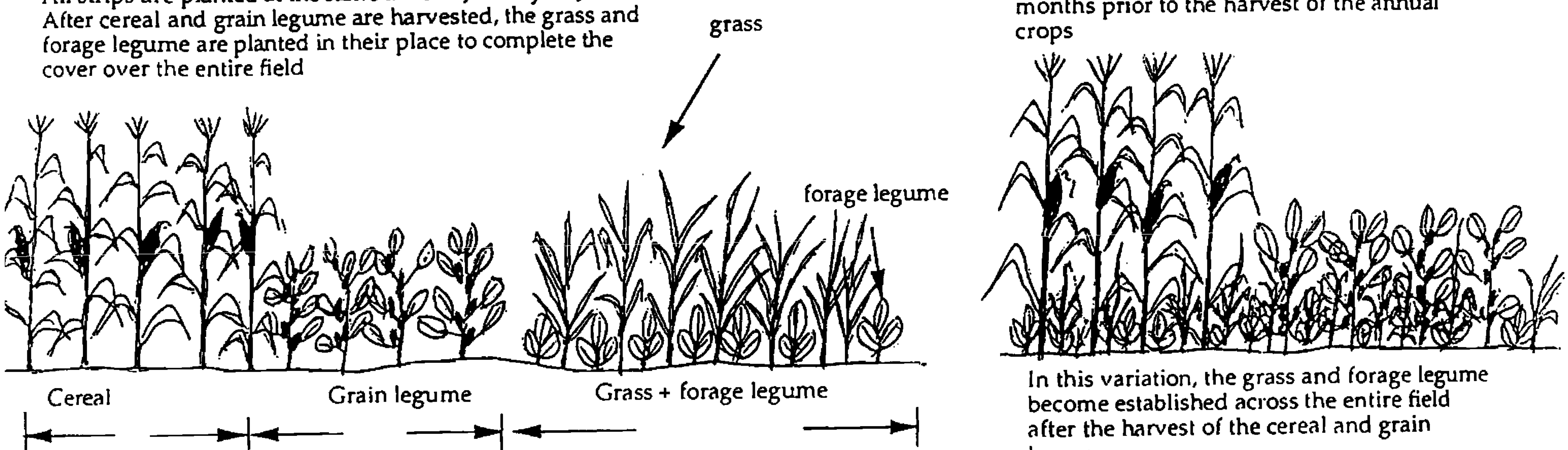
Phase II: Sowing and establishment of pasture species and livestock production (years 4 - 6)

i) Strips of cereal+grain legume intercrop and the pasture species

All strips are planted at the same time in January or June. After cereal and grain legume are harvested, the grass and forage legume are planted in their place to complete the cover over the entire field

ii) Variation of Phase II

Grass and forage legume planted in March or September as understory to cereal and grain legume 1 - 2 months prior to the harvest of the annual crops



In this variation, the grass and forage legume become established across the entire field after the harvest of the cereal and grain legume

Brachiaria brizantha or
B. humidicola or
Andropogon gayanus
+ *Centrosema acutifolium* or
C. brasilianum or
Stylosanthes capitata

Figure 3 b Phase II of crop/livestock production system in the Intermediate Savannahs of Guyana (Wickham, 1996)