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31 enero 1989

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Estimado Dr. Toledo:

Adjunto con esta carta una copia de mi informe final sobre las investigaciones que he realizado dentro del Programa de Pastos Tropicales con el apoyo de la Fundación Rockefeller y su programa de Investigaciones de Ciencias Sociales en Agricultura. Mi proyecto ha enfocado en el comportamineto de pastos mejorados seleccionados por el programa bajo condiciones ambientales en fincas y bajo el manejo de productores alrededor de Pucallpa, Perú. Además estaba estudiando los sistemas de producción vigentes en la región, las metas y recursos de los productores, y los factores limitantes que condicionan la adopción de nuevas pasturas.

En varios ocasiones hemos tenido la oportunidad de discutir el avance de mi trabajo y los resultados mas resaltantes. No creo que haya grandes sorpresas en mi informe. Pero sí creo que hay información de interés y utilidad para el Programa. El comportamiento muy variable del germoplasma bajo prueba (especialmente los problemas de establecimineto de los Centrosemas y Desmodium ovalifolium) llama la atención como temas de futuros investigaciones sobre condiciones a nivel de finca que influyen en su germinación, establecimiento y persistencia. También la falta de adaptación de estas leguminosas al fuego, un elemento del manejo actual muy común, indica que tenemos que seguir buscando nuevas materiales que aguantan el fuego y otros aspectos del manejo del productor. Los resultados de mi trabajo indican que en este momento solo contamos con una leguminosa comprobada a nivel de finca (Stylosanthes guanensis) y eso que puede tener problemas con persistencia.

En otro campo, mis estudios sobre uso de terrenos y el problema de la degradación son notables en su intento de mirar ese fenómeno desde el punto de vista del productor. Eso nos permite precisar con más exactitud que son los elementos del sistema de producción que contribuyen al mal uso del terreno, que son las consecuencias de eso para el productor, y cuales son posibles soluciones para evitar la degradación. Creo que es aquí, en el esfuerzo de evitar la degradación y recuperar areas ya degradadas, donde las leguminosas pueden jugar un papel muy positivo e importante. Pero si el Programa piensa que eso es una prioridad de investigación tenemos que ampliar nuestros criterios sobre cuales son leguminosas apropiadas y nuestros criterios de selección. Puede ser que leguminosas para recuperar areas degradadas, por ejemplo en "barbechos mejorados," tengan otros atributos que leguminosas forrajeras. En mi opinión investigaciones dirigidas a la solución del "crisis del barbecho" -- es decir de acelerar la recuperación de areas en descanso -- es un área de estudio de alta prioridad y con posibles impactos enormes.

Pero tal vez el mensaje más importante que tengo para usted y los colegas del Programa es simplemente comunicarles mis profundos agradecimientos por darme la oportunidad de trabajar con ustedes. Realmente fue impresionante la manera en que me dieron la bienvenida, me proporcionaron toda clase de apoyo técnico e intelectual y aceptaron mis sugerencias y perspectivas sobre cuestiones técnicos. Es este trato humano y profesional que me permite seguir proponiendo nuevas ideas y comentaros con la confianza que sean escuchados y respetados. Tengo mucha admiración para la dedicación de usted y todos los miembros del Programa en enfrentar el reto de alimentar los pueblos del trópico.

Otra vez, les comunico mis agradecimientos. Espero que puedo seguir contribuyendo en la medida posible al avance del programa y del CIAT en los meses y años que vienen.

Sinceramente,

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FINAL REPORT

SOCIAL SCIENCE RESEARCH IN AGRICULTURE

POSTDOCTORAL FELLOWSHIP :

The Role of Cattle in Mixed Farming Systems of the Western Amazon

William M. Loker
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1. Background

The issue of cattle-raising in the humid tropics is extremely controversial among ecologist, geographers, anthropologists and others who study this ecosystem. The clearing of vast tracts of forest in the humid tropics for extensive ranching operations or for smaller farms that have cattle raising as an important component of the production system, has raised alarm among these scientists and lately among the development community in general. Among the concerns emerging from this phenomenon are loss of biological diversity through species extinction, negative impacts on climate at the microregional, regional and global level, increased erosion and siltation of rivers and other effects that can be summed up under the rubric of "environmental degradation." An additional issue of concern that is linked to but transcends the ecological effects of livestock and agricultural expansion in this ecosystem are the social impacts. These include threats to the cultural survival of indigenous groups who live in areas such as the Amazon Basin and the Lacandon rainforest and whose lands are often usurped by agricultural expansion. In addition, critics of past development efforts claim that this process has had regressive social consequences among its supposed beneficiaries, the campesinos who have migrated to this frontier, due to the increasing concentration of land ownership and wealth which has often led to violent confrontations among small and large landowners.

The issue of agricultural and frontier expansion in the humid tropics is clearly complex. It involves social and cultural questions that transcend purely technical and economic concerns. However there are important technical and economic aspects within the debate over this process. Among the most serious charges of critics of cattle raising in the humid tropics is that livestock enterprises are not economically viable or ecologically sustainable given the production constraints prevailing in this ecosystem (particularly the Amazon Basin). In fact many critics consider that virtually all forms of agricultural exploitation, aside from slash and burn cultivation carried out at very low population densities, are non-sustainable forms of land use in this environment. Constraints to agricultural production include abiotic factors such as low levels of soil fertility, rapid leaching and volatization of nutrients applied to the soil, and in the specific case of cattle raising, physical damage to the soil. Biotic constraints include heavy pest and disease pressure including difficulty in controlling resurgent weed growth in cleared areas. Economic constraints include distance to markets and lack of infrastructure.

To the extent that the debate over colonization of "underutilized" tropical lands is about raising agricultural productivity -- and not about geopolitical questions of occupying and/or expanding the national territorial base -- technical issues are central to the debate over appropriate agricultural development policies. Without a sound, proven technological basis for highly productive and sustainable agricultural production there is little or no incentive for continuing to spend the vast sums of money necessary to develop these lands.

Although cattle-raising has been widely questioned by outside observers, it remains the most widespread land use in the American humid tropics. It is present among agriculturalists of all scales -- small, medium and large. (As will be pointed out in this report, the scale of the operation makes important differences in the production problems faced by farmers.) With rare exceptions, virtually every migrant who comes to these areas wants to incorporate cattle into their farming systems as soon as they have the capital and land resources to do so. This presents a puzzle for those striving to understand this process: if cattle-raising is unsound economically and ecologically, why is it so prevalent? Why do people choose to engage in a land use that is putatively unprofitable and prejudicial to the long-term productivity of the farm enterprise? Clearly cattle must have some attraction for frontier farmers. What are these advantages? And what are the constraints to making cattle-raising a more productive and sustainable land use in the humid tropics?

2. Pastures Research in the Humid Tropics

The research reported on in this paper was carried out in conjunction with the Tropical Pastures Program (TPP) of the Centro Internacional de Agricultura Tropical (CIAT). The goal of this program is to develop new tropical forages -- grasses and legumes-- to increase animal production on marginal and frontier lands of the American tropics. The program's principal activity has been the agronomic evaluation of promising forage species for the acid, infertile soils of the savannas and humid tropics. It is the program's philosophy that nutrition is the primary constraint to raising animal production on these lands. Improved pastures, well-adapted to abiotic and biotic conditions using low or no external inputs, are the key to increasing milk and beef production and creating economically attractive and agronomically sound farm enterprises in these frontier regions.

The TPP has a major germplasm screening site for the humid tropics in the vicinity of Pucallpa, Peru in the Peruvian Amazon. The goals of my research, conducted in the area around Pucallpa, were to study the role of cattle in the mixed crop-livestock production systems in the area and to test the adaptability and potential adoption of improved pasture species under development for this ecosystem by the TPP. The methodology employed was to carry out experiments in farmers' fields in order to judge the ability of new germplasm to adapt to abiotic, biotic and management conditions imposed in an on-farm setting. The species involved had all been selected as highly promising by the TPP in agronomic trials conducted on experimental stations. The question remained as to their response to farmer management under less controlled conditions and their impact on animal production under on-farm conditions. Working with farmers also allowed for the simultaneous study of their farming systems and adaptive strategies in order to begin to answer the question: why do farmers do what they do? And more specifically, why do farmers raise cattle?

At the outset several hypotheses were defined for testing.

1) Grass-legume pastures that are well-adapted to prevailing agroecological conditions are more productive than grass alone.

2) Appropriate grass-legume mixtures are capable of forming stable associations that are competitive biologically with aggressive native species of low productivity (weeds).

3) Grass-legume associations can be established under very low input conditions in a manner that is economically attractive to farmers.

4) The additional costs of grass-legume pastures (seeds, increased weeding, other management) are compensated by increases in animal production.

Due to the limited time period of the fellowship and the long-term nature of the research, the focus of this study was on a detailed characterization of farming systems, prevailing agroecological conditions and the factors influencing pasture establishment. It was recognized that reliable data on the impact of experimental pastures on animal production could not be obtained during the two year period of this research.

Pucallpa, Peru is located at the terminus of an all-weather road that originates in Lima and is the only point in the Peruvian Amazon connected by all-weather road with the rest of the country. It is thus an extremely important strategic point commercially and politically. It is also an area of long-term colonization along the margin of the road. Pucallpa is also located on the banks of the Ucayali River a major tributary of the Amazon and an important artery of commerce, focus of settlement (particularly of indigenous people -- Shipibo-Conibo) and zone of agricultural production.

The research entailed the planting of promising pasture species on about ten farms in the region under a variety of agroecological and socioeconomic conditions. Each stage in the agricultural cycle associated with pasture establishment was monitored and compared for improved and traditional pastures, including: clearing, burning, planting (with or without food crops), establishment, grazing and maintenance. My study area was centered on the experimental station where CIAT performs its agronomic research about 59 kms from Pucallpa on the main road. Initially the study area extended from the outskirts of Pucallpa to about 130 kms from the town along the road to Lima. Along the length of this road, the area can be roughly divided into three environmental zones:

1) a relatively flat plain that extends away from the Ucayali River to about Km 30 along the road;

2) an area characterized by undulating topography which extends from Km 30 to about Km 90 along the road; and,

3) an area of extremely hilly topography with steeper slopes which extends from Km 90 to the limits of the study area (Km 130) and beyond.

Elevation ranges from about 250 meters above sea level near Pucallpa to around 400 m.a.s.l. in the hilly area. There is a gradient of increasing rainfall along this transect as well, with rainfall highest in the hilly area (around 3,000 mm) and lowest around Pucallpa (about 1,800 mm, Figure 1 displays the monthly pattern of rainfall for the Pucallpa region). In order to understand the range of conditions facing farmers in the area, the project attempted to study farms located in each of these environmental zones.

In addition to studying farms under a variety of agroecological conditions, it was also necessary to studying farms with varying socioeconomic conditions. Thus in the process of selecting participants in this research an attempt was made to choose farms of varying resource endowments in terms of size, number of animals and in terms of geographic origin and length of residence of the farmers. The general characteristics of participating farms is listed in Table 1.

Selection of participating farmers was limited by certain particular characteristics demanded by this research. For example it was decided at the outset to plant pastures in areas of secondary vegetation or bush fallows (termed "purmas" locally and throughout this paper) thus avoiding the planting of pastures either in virgin forest or areas currently in (degraded) pasture. (The latter present difficult technical obstacles and the former an unnecessary waste of a resource.) Farmers commonly plant pastures (with or without accompanying annual crops such as maize) in purmas after clearing and burning. The project sought out farmers that were planning to clear and plant areas of purma that particular crop year (1987). A more stringent criterion that eliminated many farmers from consideration was the need to work with farmers who milked their cows on a regular basis. This was due to the convenience of measuring the impact on animal production through increased milk production. Milk is a fairly sensitive indicator of nutritional status, easily measured and that responds swiftly to changes in diet. Thus animals could be grazed alternately in improved and control pastures for periods of ten days or two weeks in each paddock and the hypothesized improvement in diet provided by the experimental treatment would be measurable. This criterion eliminated a significant number of farmers from consideration-- both at the large and small end of the scale -- who do not milk their animals. It is recognized that this approach had the effect of biasing the sample toward those farmers who dedicate more time to cattle-raising and for whom cattle are a relatively more important source of income.

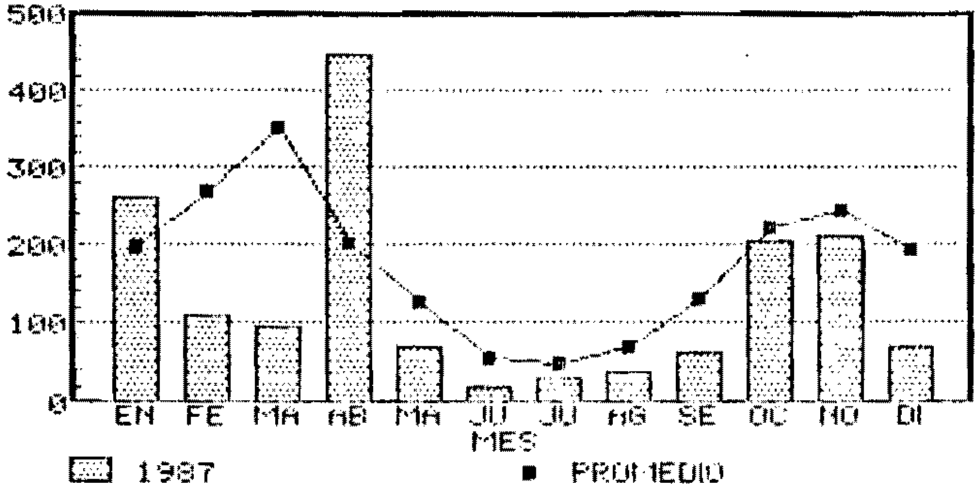


Figure 1. Monthly Rainfall distribution, Pucallpa

Table 1. General characteristics of farms

Farm #	Location (km)	Size (has)	Pastures (has)	Brachiaria (has)	Cattle (head)	Other stock
1	16	49	37	12	52	1
2	39	300	120	35	56	79
3	66	60	10	10	12	10
4	71	60	10	10	30	17
5	69	24	14	14	35	3
6	70	48	36	34	51	20
7	71	60	49	15	70	6
8	77	104	60	50	60	11
9	79	100	40	7	25	6
10	70	50	10	5	27	2
11	109	36	28	0	30	0
12	112	50	20	18	30	0
13	129	200	150	9	200	0
	TOTAL	1,141	533	215	678	115
	MEAN	87.7	48.5	16.5	54	14
	S.D.	78	46.3	14.4	51	22

Location: refers to distance from Pucallpa along central highway.
Pastures: area of farm in pasture, according to farmer.
Brachiaria: area in farm in Brachiaria decumbens.
Other stock: refers to other grazing animals besides cattle such as horses, sheep, etc.

In concrete terms the research strategy was to plant improved pastures in a side-by-side comparison with the most popular local pasture (the grass, Brachiaria decumbens) on plots selected by the farmers. These plots varied from two to ten hectares with half the area planted to the control and half to the experimental species. The project provided seed for the experimental pastures, barbed wire to fence in the plot and technical assistance at the time of planting together with monthly follow-up visits to monitor pasture performance and discuss any problems with the farmer. The farmer provided land, labor, planting material for the control and agreed to provide animals for grazing the plots once they were established. In addition the farmer agreed to record data on labor input and milk production and allow us access to the pastures at any time for measurement purposes. Two different experimental mixtures were planted in farmers fields. The species and accessions utilized are listed in Table 2.

Table 2. Species and accessions of pastures sown in on-farm trials, Pucallpa, Peru

Species	kg/ha
Association # 1	
Brachiaria decumbens 606	2.0
B. dictyoneura 6133	1.5
Stylosanthes guianensis 136 & 184	3.0
Centrosema macrocarpum 5713	0.5
C. acutifolium 5277	1.0
C. pubescens 438 & 442	0.5
Desmodium ovalifolium 350	0.5
Association # 2	
Andropogon guyanus	10.0
Stylosanthes guianensis 136 & 184	3.0
Centrosema macrocarpum 5713	0.5
C. acutifolium 5277	1.0
C. pubescens 438 & 442	0.5

The project was initiated with the participation of 14 farmers between km 16 and km 130 along the main road with the knowledge that there would be a certain amount of attrition as the project progressed. By June 1988 the four farms located in the third environmental zone were eliminated from the study due to political violence in this area. Two other farms closer to town also dropped out for reasons unrelated to the project. Thus the project finished with 8 farms where pastures were planted, their establishment studied and which continue to be monitored for impact on animal production and persistence over time.

3. Research Results

3.1 Pasture establishment

Ease of pasture establishment is a critical consideration for farmers in the region. Due to shortages of capital and labor, farmers are interested in species that establish reliably with a minimum of purchased inputs and management. Most farmers establish pastures together with annual crops and pastures represent a low cost investment once land has been prepared. Ideally the farmer wants a pasture that will take root, spread rapidly and compete aggressively against invasive weeds. Therefore information on rate of establishment and cover along with any changes in management required by the experimental species is important to assess the potential for adoption of these species.

The project was interested in determining the key factors influencing successful pasture establishment. There were a number of implicit assumptions regarding the nature of these key factors that guided selection of variables for measurement.

1) **biomass and botanical composition of the <u>purmas</u> before burning:** the quantity and type of vegetation present reflects past land use and fallow time and influences pasture establishment through its contribution to soil fertility as ash after burning and through suppression of weeds throughout the fallow period.

2) **physical and chemical status of the soil:** soil fertility and permeability were considered obvious factors influencing pasture establishment; both parameters were measured before and after burning and will continue to be measured periodically throughout the life of these experiments.

3) **management:** including the timing of agricultural activities and effectiveness of clearing and burning and particularly labor input in weeding the pastures during the establishment phase.

In order to adequately characterize the plots prior to clearing and burning, the following variables were measured in a 10 x 50 mt sample transect:

1) **Biomass:** height and diameter of all trees over 5 cm in diameter was noted, along with the tree's common name, in order to estimate biomass and species diversity. In

addition, a subsample of all tree seedlings at least 1.3 mts tall was recorded within a randomly chosen 10 x 10 meter area within the larger sample transect. Biomass was estimated using regression equations developed for similar conditions in Brazil by Uhl, Buschbacher and Serrao (in press).

2) **Soil chemistry:** two composite soil samples formed of three randomly selected samples each, and divided into two strata (0-20 cms and 20-40 cms) were taken from each transect before and after burning.

3) **Soil structure:** was studied through measuring infiltration rates of water using standard agronomic technique (concentric cylinders). Bulk soil density was also measured using cylinders placed at 0-15, 15-30 and 30-45 cms depth.

4) **Other measurements:** Leaf litter was measured by visual assessment of percent coverage and ten randomly spaced measurements of the depth of leaf accumulation.
Other parameters measured included slope and notation of the presence or absence of grasses or aggressive pasture weed species.

Characterization of the purmas contributes to our understanding of key factors in pasture establishment. In addition these data form a benchmark for repeated measurement to analyze the effect of the pasture and grazing on the parameters measured (especially soil chemistry and structure) over the life of the experiment. Results of the vegetation study are presented in Table 3. We will return to this data when we consider the variable rate of pasture establishment and amount of forage produced in these plots.

The key to successful pasture establishment is that the planted species cover the bare ground rapidly and compete effectively for light, water, soil nutrients and space with weeds. The farmer influences this process through site selection, and subsequent management such as the effectiveness in clearing and burning, timing of agricultural activities especially planting and through timely weeding during pasture establishment. Thus there exists a complex relationship between the pre-existing conditions of a given plot (soil and vegetation) and the skill of the farmer in bringing this plot into production. His success is measured in terms of crop yield and in the case of pasture in the rate of establishment and the amount of forage available for grazing. The end product of a pasture is, of course, animal production -- either milk, meat or both.

Project measures of pasture establishment focused on two parameters: cover and botanical composition. Pasture establishment was measured on a monthly basis starting six weeks after planting and continuing until the establishment phase was complete, eight months after planting. Cover and botanical composition were measured using a visual assessment of the presence of planted species versus weeds in a one meter square sampling frame placed randomly throughout the study plot. One hundred

Table 3. Biomass of <u>purma</u> vegetation in experimental plots before burning

Farm #	Biomass (kg/ha)	# of Spp	Trees/ hectare	Trees >5 cm/ha	Avg Dia/Ht	Avg Max Dia/Ht
1	18,266	nd	17,000	700	2.6-3.1	12.2- 8.1
2	60.953	19	8,300	1,800	5.5-7.2	17.1-18.6
3	27,680	nd	16,440	540	2.4-3.6	9.0- 9.2
4	27,098	14	7,440	840	3.2-3.5	17.0-13.1
5	48,762	16	5,400	1,400	6.5-6.5	16.0-13.2
6	22,630	14	7,440	740	3.8-5.2	12.5-16.8
7	58,426	nd	11,760	1,360	4.5-4.7	16.8-16.2
8	29,403	18	3.280	580	5.6-6.8	17.8-23.0
9	25,923	nd	9,520	920	2.9-4.6	8.8-15.0
10	73,567	24	6,100	1,100	6.5-7.5	30.5-20.8
11	110,236	12	7,560	1,760	6.5-8.7	19.5-23.2
12	80,085	31	7,100	1,300	6.2-6.9	30.0-19.3

Biomass refers to woody arboreal vegetation, does not include vines or herbaceous plants.
# of Spp: refers to number of species identified; all cases included some unidentified trees not included in this total.
Trees/hectare: is extrapolated from a 10 x 50 mt sample transect.
Trees > 5 cm/ha: is extrapolated from a 10 x 50 mt sample transect.
Avg dia/ht: diameter in cms, height in meters.
Avg Max dia/ht: based on the five largest trees within the 10 x 50 mt sample transect.

readings per hectare were performed in which the approximate cover of various classes of weeds, each planted species (grasses and legumes) and bare earth was noted. An overall estimate for botanical cover of the plot estimated from this sample. Examining the floristic evolution of the study plots over time provides the basic data to compare pasture establishment among study plots under a variety of agroecological and management conditions. The following section will compare the rate of coverage and changes in botanical composition under a variety of conditions in order to analyze key factors influencing pasture establisment.

3.1.1. Case A: Short fallow purma with and without weeding (Farms 1 and 3)

The first case to be discussed is that of pasture establishment after a short fallow cycle with and without weeding by the farmer during the establishment phase. Table 4 presents selected the purma vegetation prior to clearing and burning. Note that Farm 1 had low biomass (lowest of all the purmas measured) with numerous small trees. Farm 3 also has relatively low biomass with trees only slightly larger. In general the two lots are quite similar in terms of the vegetation prior to clearing and burning and fallow time.

Table 4. Selected Attributes of Experimental Plots, Farms 1 & 3

	Farm 1	Farm 3
Years of fallow	4	4
Biomass (kg/ha)	18,266	27,680
Trees/ha	17,000	16,440
Trees > 5cm Dia/ha	700	540
Avg Dia/Ht	2.6/3.1	2.4/3.6

Table 5 compares the chemical analysis of the upper 20 cms of soil in both lots both prior to and after burning. Before burning both lots were quite similar in their chemical characteristics. Farm 3 had slightly more calcium, magnesium and potassium. These differences were somewhat accentuated after the burn (attributable perhaps to the slightly higher biomass and more complete burn achieved on Farm 3) but in general there were not marked differences between the soils of the two lots. Therefore we can conclude that we are dealing with broadly similar initial conditions in comparing Farms 1 and 3.

Figures 2 and 3 illustrate the pattern of pasture establishment in the two plots. The figures are graphic representations of the changing proportions of pasture grasses, legumes, weeds and bare earth. As can be noted there are certain general characteristics that the two plots share: both start with relatively high percentages of bare earth and weeds with an increasing percentage of planted species over time. But there are marked differences in the evolution of the two plots worth noting.

Table 5. Chemical analysis of upper 20 cms of soil, before and after burning: Farms 1 and 3

	pH	Ca -- meq	Mg /100 gr --	Al	% Sat Al	% OM	P ppm	K meq/100 gr
Before Burn								
Farm 1								
Sample 1	4.0	0.65	0.30	2.7	74	2.00	5.3	0.13
Sample 2	3.8	0.63	0.30	4.1	81	2.90	2.7	0.14
Farm 3								
Sample 1	3.8	0.64	0.59	6.9	85	2.44	3.3	0.18
Sample 2	3.9	1.37	0.56	4.0	67	3.34	5.2	0.22
After Burn								
Farm 1								
Sample 1	3.8	0.75	0.36	3.8	77	3.69	4.3	0.19
Sample 2	3.8	1.07	0.42	2.5	62	2.84	4.5	0.17
Farm 3								
Sample 1	3.9	2.29	1.11	0.9	21	2.36	3.3	0.17
Sample 2	4.1	2.24	0.69	3.6	55	2.72	5.6	0.26

From the outset there is a greater percentage of weeds in the plot of Farm 1 and less bare earth. This is due in large measure to the effectiveness of the clearing and burning of the respective lots. As mentioned, the plot of Farm 3 burned thoroughly eliminating nearly all the cleared vegetation and providing a weed-free environment for sowing of crops and pastures. (Both farmers planted maize with pastures and both lost the maize crop to drought.) The plot on Farm 1 did not burn completely sparing some weedy vegetation which continued unimpeded growth.

But the major difference between the two lots is the management given subsequent to the burn. The owner of Farm 1 did not weed his plot once during the entire establishment phase. In contrast the owner of Farm 3 gave three weedings to his plot starting six weeks after sowing and periodically thereafter investing about 26 man days in weeding in his 1.5 hectare plot. This explains the rapid

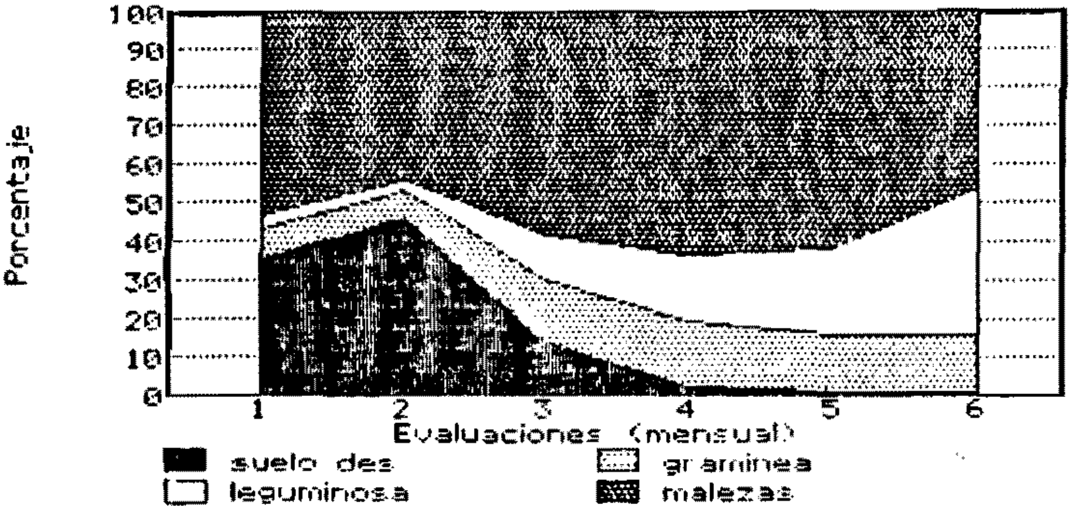


Figure 2. Rate of pasture establishment, Farm 1

Note: <u>suelo des</u> = bare earth <u>graminea</u> = pasture grass
<u>leguminosa</u> = pasture legumes <u>malezas</u> = weeds

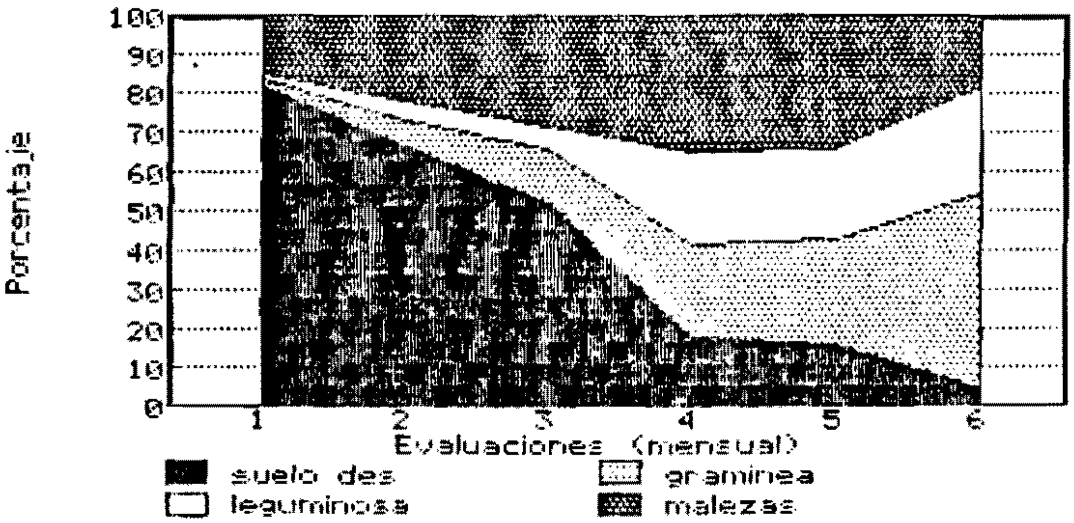


Figure 3. Rate of pasture establishment, Farm 3

decrease in bare soil exhibited in Farm 1 as the resurgent weeds and pastures rapidly cover the ground while bare earth remains a significant (though decreasing) portion of total area on Farm 3 due to the frequent elimination of invasive flora.

The most notable effect of weeding is in the higher proportion of pasture species on Farm 3 which has about 75% planted pasture at the end of the evaluation period compared with slightly less than 55% on Farm 1. At the end of the establishment period, the experimental plot on Farm 3 was composed of 75% pasture (50% pasture grasses and 25% legumes -- mostly <u>Stylosanthes guianensis</u>), 20 % weeds (half of which was kudzu -- <u>Purarea phaseoloides</u>, a naturally-occurring forage legume with the remainder other broad-leafed and narrow-leafed weeds) and 5% bare soil. Farm 1 had 54% planted pastures (16% grasses and 38% legumes, virtually all of the latter <u>S. guianensis</u>), 45% weeds (of which slightly more than half is kudzu) and less than 1% bare soil. It is interesting to note that weeding not only favors the planted species in general, it also seems to favor the planted grasses (<u>B. decumbens</u> and <u>B. dictyoneura</u>). Both pastures have an adequate percentage of legume (<u>S. guianensis</u>) but the pasture in Farm 1 has a very low percentage of forage grasses. This seems to be due to the shading caused by the vigorous weed growth that causes lower growth rates among the grasses than among the more shade tolerant legumes.

Naturally the question arises: is it worth the investment of 26 man days of labor to obtain 15% more pasture? It has been mentioned that labor is a scarce resource in the region. The question can not be answered definitively due to various factors.
One is the opportunity cost of the labor involved. For example the owner of Farm 3 has more family labor available than the owner of Farm 1: 75% of the labor invested by the owner of farm 3 was family labor. Also the owner of Farm 1 lives only 16 kms from Pucallpa and has easy recourse to off-farm labor to earn cash, which competes with on-farm activities.

Another important factor is that of the effect of weeding on the rate of pasture establishment. The plot on Farm 3 was ready for grazing as soon as the legumes finished flowering and dropping seed at the end of the dry season. The strategy of Farmer 1 was to control weeds through burning the plot at the end of the dry season. He then had to wait for the pasture to resprout after burning -- a wait of about three months. Therefore weeding not only provided the owner of Farm 3 with 15% more pasture, he gained about three months production time over Farm 1. On both farms pasture is in short supply given the number of animals so weeding provides a clear advantage to the owner of Farm 3.

A final word before leaving this case. It was impressive to see the planted pasture species establish in very poor soils, after a relatively brief fallow period. Even in conditions of relatively low biomass purmas with vigorous weed competition the pastures established successfully. In addition the pastures were planted on Farm 3 and under rather stressful climatic conditions. Both farmers lost their crop of maize to drought. The pastures were planted on Farm 3 earlier than Farm 1 during the relatively dry period. Though the drought slowed plant growth and establishment. the plants survived in soil that was extremely hard and dry.

3.1.2. Case B: Intermediate fallow purma with and without weeding (Farms 5, 7 and 10)

The next case deals with a similar situation as that previously described: similar initial conditions prior to planting with variable management during the establishment phase. In this case we are dealing with plots that had slightly longer fallow periods-- five to six years. On two farms (5 and 7) the owners weeded the plots while in the case of Farm 10 the owner did not weed during the entire establishment phase. Table 6 presents comparative data on biomass among the plots.

Table 6. Selected Attributes of Experimental Plots. Farms 5,7 &10

	Farm 5	Farm 7	Farm 10
Years of fallow	5	5	6
Biomass (kg/ha)	48,762	58,426	73,567
Trees/ha	5,400	11,760	6,100
Trees > 5cm Dia/ha	1,400	1,360	1,100
Avg Dia/Ht	6.5/6.5	4.5/4.7	6.5/7.5

As can be noted, Farm 10 has the highest biomass which is presumably related to its slightly longer fallow period. The vegetation on Farm 5 resembles that of Farm 10 in terms of the number and size of trees present, but Farm 10 surpasses the Farm 5 due to a few very large individual trees that were present on the lot. The vegetation of Farm 7 is smaller but more dense than that of Farm 5 therefore having a higher total biomass than Farm 5. In terms of the history of land use, Farm 5 had a rather light use before this fallow period; the virgin forest was felled and one harvest of rice was obtained before the land went back to fallow. On Farm 7 the forest was felled and one harvest of maize was obtained then the lot was rested 4-5 years and yuca was planted. It is after this harvest of yuca that the area was fallowed for five years. Land use in Farm 10 was similar to that of Farm 5: a very old secondary forest was felled and one rice crop harvested.

then the area was left fallow for six years. It is worth noting that in no case was the land used for grazing.

Table 7 presents the comparative analysis of soil chemistry of the three lots. Note that before burn the soils exhibit broad similarities with the soils on Farm 5 having slightly higher contents of calcium, magnesium and phosphorous and aluminum saturation slightly lower than the other two soils. The soils of Farm 10 are slightly superior to those of Farm 7 for most nutrients. The minor differences between the soils of Farm 5 and the other two farms are increased after the burn displaying significantly higher levels of all the nutrients analyzed and much lower levels of aluminum saturation. In all cases the soils illustrate the positive effect of the burn and the incorporation of ash from the burned vegetation.

Table 7. Chemical analysis of upper 20 cms of soil, before and after burning: Farms 5, 7 and 10

	pH	Ca	Mg	Al	% Sat	%	P	K
		-- meq /100 gr --			Al	OM	ppm	meq/100 gr
Before Burn								
Farm 5								
Sample 1	4.2	3.41	0.80	4.2	50	1.78	3.3	0.13
Sample 2	4.1	2.47	0.60	2.1	41	2.22	4.8	0.16
Farm 7								
Sample 1	4.0	0.60	0.41	3.6	78	2.44	2.2	0.11
Sample 2	3.9	0.49	0.35	4.2	83	2.44	4.2	0.11
Farm 10								
Sample 1	4.2	1.05	0.35	2.5	64	1.34	3.0	0.13
Sample 2	4.2	2.06	0.49	1.3	34	1.56	3.7	0.10
After Burn								
Farm 5								
Sample 1	4.8	4.59	1.19	0.0	0	2.36	15.7	0.64
Sample 2	4.5	6.09	1.57	0.5	6	2.84	15.5	0.48
Farm 7								
Sample 1	4.0	1.59	0.80	2.4	50	2.84	8.3	0.31
Sample 2	4.1	1.93	0.80	1.5	35	2.96	10.0	0.24
Farm 10								
Sample 1	4.1	1.70	0.59	1.0	30	2.11	6.6	0.23
Sample 2	4.3	2.70	0.63	0.3	8	2.11	4.5	0.17

Turning our attention to Figures 4,5 and 6 we can follow the floristic evolution of the lots over the establishment period. Figures 4 through 6 are presented in the same format as Figures 2 and 3 above, displaying the percentages of bare soil, weeds and forage grass and legumes. In reality we have three different management strategies represented in these three cases. For example, all three farmers planted maize (though on Farm 10 only about 20% of the lot was sown), Farm 7 lost the crop to drought and invasion by cattle while Farm 5 harvested about 1,500 kg/ha of maize. The lot on Farm 5 was weeded three times during the course of the growing season of the maize crop -- once at six weeks after planting, again at three months and finally when the corn was harvested the farmer performed a third weeding. The maize heavily shaded the pasture plants causing some delay in their initial establishment, but once the leaves of the corn dried, allowing light to reach the plants (between the third and fourth evaluation) one notes a rapid increase in pasture growth.

Again, weeding proves to be an important management factor in pasture establishment. The owner of Farm 7 invested 56 man days in the weeding of his plot, the owner of Farm 5 invested 19 man days and the owner of Farm 10 did not weed. Again we see that the primary effect of the weeding is to favor the Brachiaria. Farm 5 ends with 20%, Farm 7 with 17% and Farm 10 with 14%. Total planted pasture (grasses plus legumes) is 68% for Farm 5, 83% for Farm 7 and 62% for Farm 10. The difference between Farms 5 and 10 is not great, however bear in mind that the owner of Farm 5 also harvested 1,500 kgs/ha of maize -- a significant offtake of biomass from a crop competing heavily for light, nutrients and water with the pastures.

As in the previous case, the owner of Farm 10 -- who did not weed -- burned his plot at the end of the dry season in an effort to control weeds. The burn was extremely thorough and the plot will need at least three months to recover before grazing. Both plots on Farm 5 and 7 are already under grazing.

Another interesting fact that emerges from this data is that the problem with weeds was relatively less severe when comparing Farms 10 and Farm 1 in the previous example. Neither farmer weeded, yet the plot on Farm 1 ended up with 62% weeds while Farm 10 only had 32% with no weeding. This reflects the effect of the longer fallow on weed suppression. The 56 man days invested in weeding the plot on Farm 7 represents a significant effort on the farmer's part, but also reflects the relative labor surplus obtaining in his household with four working-age males living in the household and contributing labor on the farm. The effort shows in the results as well -- a largely weed-free pasture.

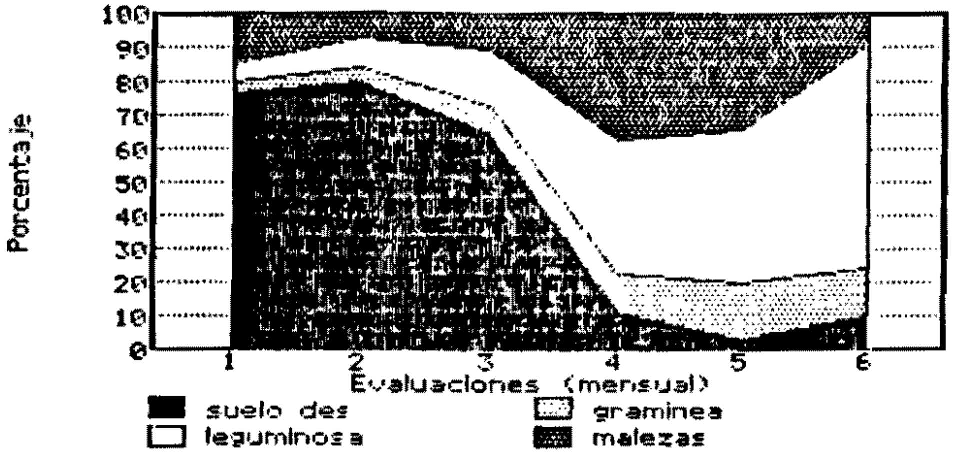


Figure 4. Rate of pasture establishment, Farm 5

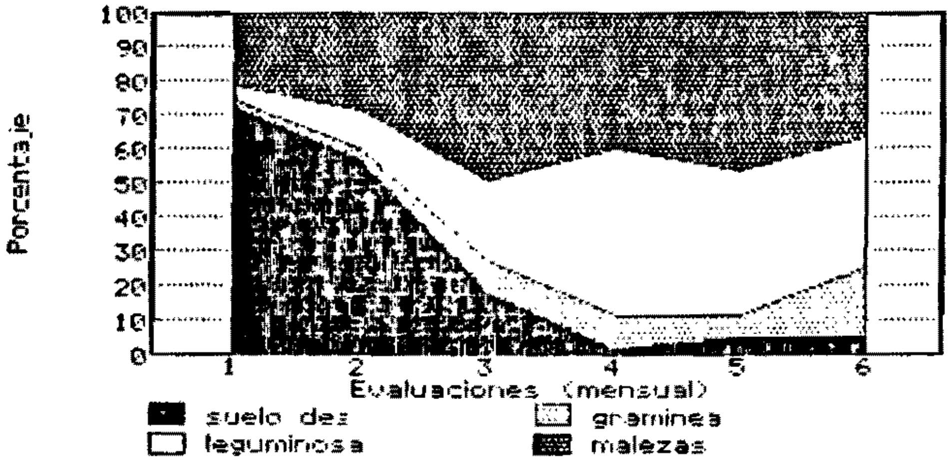


Figure 5. Rate of pasture establishment, Farm 7

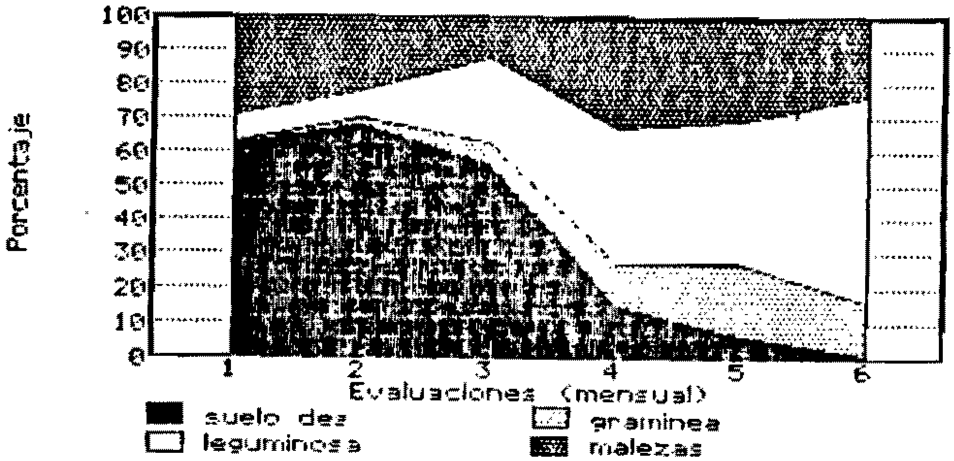


Figure 6. Rate of pasture establishment, Farm 10

3.1.3. Case C: Andropogon guyanus in a short and long fallow purma (Farms 2 and 8)

This case differs from the two previous examples in that here we are departing from quite different initial conditions and seeing the response of the germplasm to these differences. This case concerns the sowing of the grass, Andropogon guyanus, associated with S. guianensis, Centrosema acutifolium, C. macrocarpum, and C. pubescens. Table 8 shows the difference in vegetation found on these lots prior to burning. The lot on Farm 8 has low biomass due to relatively low tree density with few trees more than 5 cm in diameter. The lot on Farm 2 has about double the biomass, double the number of trees per hectare and more than three times as many trees over 5cm in diameter per hectare. In addition, there was a significant presence of kudzu and pasture weeds in the lot of Farm 8 which was not noted on Farm 2.

Table 8. Selected Attributes of Experimental Plots, Farms 2 & 8

	Farm 2	Farm 8
Years of fallow	8-10	5
Biomass (kg/ha)	60,953	29,403
Trees/ha	8,300	3,280
Trees > 5cm Dia/ha	1,800	580
Avg Dia/Ht	5.5/7.2	5.8/6.8

Table 9 presents the comparative soil analysis for the two plots. Surprisingly enough the soil chemistry the lot on Farm 8 is superior to that of Farm 2 despite the shorter fallow period and less exuberant biomass. Farm 8 shows higher content of calcium, phosphorous and magnesium with lower levels of aluminum saturation, a situation that prevails both before and after the burn. I find these soil data rather anomalous and difficult to explain.

Figures 7 and 8 illustrate the floristic evolution of the two parcels. Note that at the time of the first evaluation the percentage of bare soil is about the same on the two lots (60% on farm 8 and 65% on Farm 2) but that from the beginning farm 8 displays a higher percentage of weeds (25% vs 18% on Farm 2). The marked difference is in the very low percentage of sown pastures on Farm 8 compared with Farm 2 (5% vs 10%). Over time the weeds increase dramatically on Farm 8 ending up covering 80% of the lot.

Table 9 Chemical analysis of upper 20 cms of soil, before and after burning: Farms 2 and 8

	pH	Ca	Mg	Al	% Sat	%	P	K
		-- meq /100 gr --			Al	OM	ppm	meq/100 gr
Before Burn								
Farm 2								
Sample 1	3.5	0.29	0.35	6.7	91	2.44	2.4	0.21
Sample 2	3.7	0.21	0.29	5.2	91	2.22	3.4	0.24
Farm 8								
Sample 1	4.1	1.10	0.61	4.1	66	1.78	3.7	0.21
Sample 2	4.0	1.73	0.83	3.9	60	1.78	5.4	0.17
After Burn								
Farm 2								
Sample 1	3.4	0.61	0.55	5.7	83	2.96	5.4	0.34
Sample 2	3.7	0.65	0.73	4.0	74	2.84	4.6	0.40
Farm 8								
Sample 1	3.6	1.47	0.72	2.3	51	2.48	4.2	0.27
Sample 2	3.9	3.18	1.49	1.6	17	2.72	7.2	0.35

at the end of the evaluation period. On Farm 2 the weeds end more or less where they started at 15% of the coverage. Farm 2 ends with 65% pastures at the end of the evaluation period (after reaching a peak of almost 75%) while on Farm 8 the pastures end up at about 20% of the total coverage. What happened in this case?

The results in this case are a combination of differences in initial conditions, especially in terms of the land use history of the two lots, and of mismanagement of the lot on Farm 8. The lot on Farm 8 was a very tall purma about 9 years ago. It was cleared and burned and maize was planted along with pastures (*Hyparrhenia rufa*, Yaragua). The lot was grazed for three years after which the owner let it revert to purma for five years, the fallow period prior to this cycle. I feel that the previous use of this lot as a pasture was an important factor in the difficulties experienced in establishing pastures this cycle. The most difficult problem encountered here was a copious and highly aggressive weed population, which was difficult to control and ended in dominating the lot. From the outset there was a problem with the spontaneous invasion of kudzu -- which is a forage legume that has become naturalized in the zone. The kudzu regenerated from plants that survived the burning of the lot and from seed reserves in the

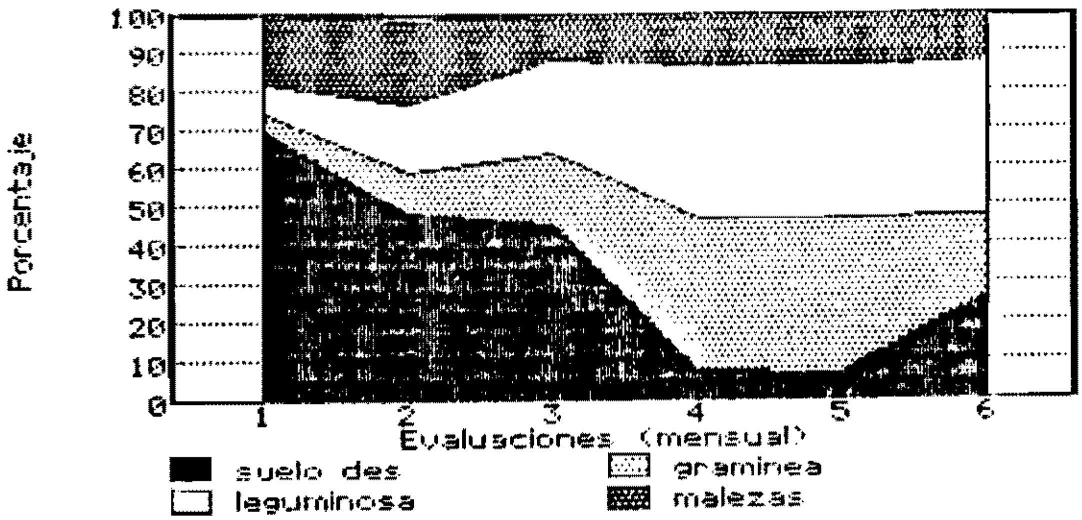


Figure 7. Rate of pasture establishment. Farm 2

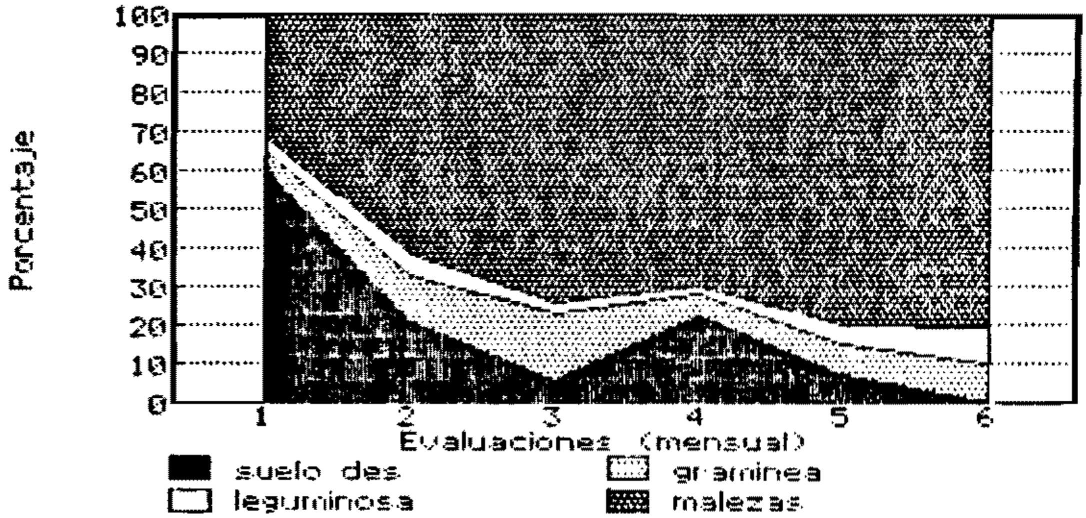


Figure 8. Rate of pasture establishment, Farm 8

soil. Kudzu in itself is not negative, but in this case it was so aggressive that it was smothering the *Andropogon* and planted legumes. I suspect that it previous use as a pasture contributed to the high weed population in this lot.

Apart from this there were certain errors in management that contributed to the establishment problems on this lot. When the weeds grew out of hand we asked the farmer to weed. He agreed but first wanted to graze the lot to eliminate some of the weeds and make access easier. The lot was grazed in March (between the third and fourth evaluations). Note the increase in bare soil and the decrease in pasture caused by the grazing. The grazing was too heavy (10 animal units for three weeks on 2 has) almost eliminating the *Stylosanthes*, grazing back the *Andropogon* severely, but without affecting the kudzu to the extent desired. At the time of the fourth evaluation the *Andropogon* was recovering and entering into flower, the *Stylosanthes* was being smothered by the kudzu, the broad-leafed weeds were being reduced by weeding, and the kudzu was growing at a brisk rate. If we examine Figure 9 we can see the botanical composition of the lot on Farm 8 eliminating bare soil from the analysis and separating out the kudzu from broad-leafed weeds. Note the tremendous increase in kudzu after the fourth evaluation, the effect of grazing on the *Stylosanthes* and *Andropogon* and the effect of weeding on the percentage of weeds. The final periods of evaluation show a very slight recovery of the planted pastures but continued dominance of the kudzu.

The management strategy followed by the owner of Farm 8 to control weeds was to burn the lot in an attempt to control the kudzu and encourage the grass. The burn was moderately effective and in the aftermath the *Andropogon* has regenerated quite adequately, the kudzu is present at reduced levels and the *Stylosanthes* is virtually eliminated. The end result is a grass-legume association of *Andropogon guyanus* and kudzu -- not entirely negative outcome but not expected. (When this result was presented at the internal review of the TPP it provoked a spirited discussion of the potential of kudzu as a forage legume; it has been systematically evaluated by the program but is not being promoted as a promising species at this time.)

The case of Farm 2 was quite different. Because it was a relatively high biomass purma representing a long fallow period the weeds which emerged were largely arboreal or shrubby and easily controlled. A single weeding between the second and third evaluation was sufficient to control these weeds to the extent necessary for the planted species to become vigorously established. The amazingly rapid growth of the *Andropogon* (an upright grass) helped to control the weeds. Between the fourth and fifth evaluation the *Andropogon* entered into flower and dried up. The

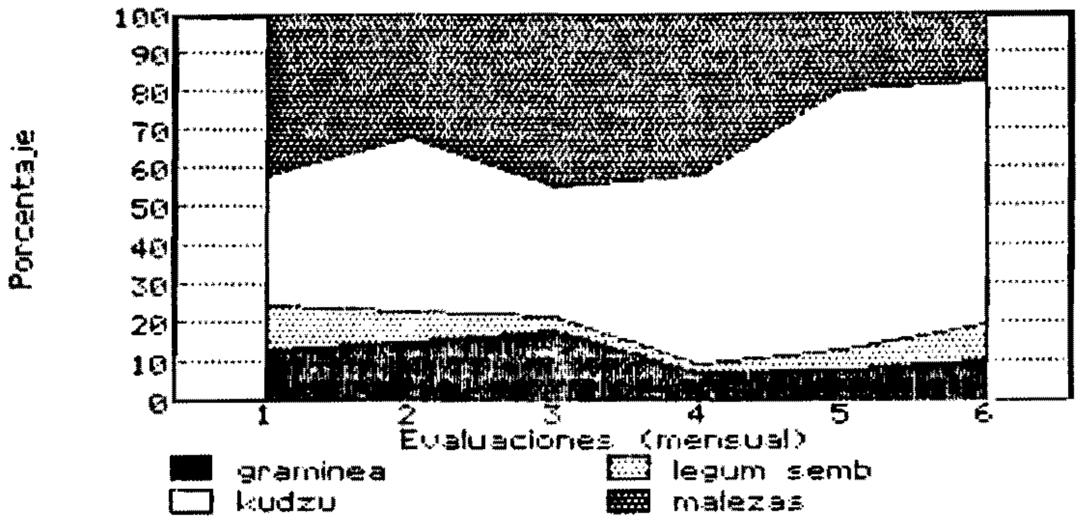


Figure 9. Botanical composition of pasture, Farm 8

reduction in Andropogon noted between the fifth an sixth evaluation is due to the harvest of grass seed carried out by the owner of the lot. He was so impressed with the growth of the plant that he organized the harvest and plans to sow an additional the hectares the coming year. He also harvested 45 kgs of Stylosanthes for planting with the Andropogon.

What are the lessons learned from this experience? First, Andropogon guyanus is an appropriate forage for certain conditions in the humid tropics. Its upright growth habit makes it less competitive with weeds and it should not be sown where heavy weed infestations are anticipated. In regions such as the study area where there is a high dependence on a single forage species (Brachiaria decumbens) diversification of the genetic base is strongly recommended, all the more so given the serious problem that B. decumbens has with insect pests in other parts of the humid tropics. The experience with Andropogon is a good reminder that the term "improved pasture" is context specific. The question raised in this case regarding the effect of grazing on subsequent fallow cycles will be explored in more detail in the next example.

3.1.4. Case D: Pasture in degraded purma (Farm 4)

In the previous case I mentioned my suspicion that the previous use of the experimental parcel in Farm 8 as a pasture was a contributing factor to the difficulty in establishing pasture after the fallow period. Why would this be so? The present case is an example of attempting to establish the Brachiaria- based association on a lot that was previously grazed for five years. The owner of Farm 4 cleared the lot of virgin forest 13 years ago and planted maize with pasture (Hyparrhenia rufa, yaragua). The lot was grazed for five years during which time the farmer battled constantly against weed invasion before abandoning the lot to eight years of fallow. It was this eight years of secondary growth--purma -- that was cleared and burned to plant the Brachiaria association.

Table 10 presents the attributes of the purma of Farm 4 before clearing and burning. Also presented by way of comparison are the data from Farm 2, another purma of about eight years fallow. Notice that the purma of Farm 4 has less than half the biomass of Farm 2 after a nearly equivalent period of fallow time. It is roughly equivalent to the biomass accumulation displayed by a purma of four years (cf. Farm 3 in Table 3).

Table 10. Selected Attributes of Experimental Plots, Farms 2 & 4

	Farm 2	Farm 4
Years of fallow	8-10	8
Biomass (kg/ha)	60,953	27,098
Trees/ha	8,300	7,440
Trees > 5cm Dia/ha	1,800	840
Avg Dia/Ht	5.5/7.2	3.2/3.5

There are notably fewer and smaller trees in the purma of Farm 4 compared with Farm 2. The lot looked different as well. Most of the purmas were dense thickets of tress and vines that were difficult to penetrate and work in. The purma of Farm 4 had open vegetation with scattered trees of middling stature with a few large trees distributed throughout the lot (mostly guayaba, Psidium guajaba) and a grassy floor composed of remnants of the yaragua and narrow-leafed weeds, together with persistent pasture weeds such as Pseudelephantopus spicatus (matapasto) various weedy Desmodium spp. (pega-pega), Sida rhombifolia (sinchipichana) and others. It did not have the closed canopy and near continuous cover of fallen leaves on the ground typical of other purmas.

This situation was due to various factors related to the lots previous land use as a pasture. The farmers struggle to control weeds was successful in controlling the easily eliminated arboreal flora typical of early successional vegetation. Manual control with a machete combined with frequent use of fire effectively eliminated pioneer species such as ceticos (Cecropia spp.), topas (Ochroma pyramidalie) and atadijo (Trema micrantha). This effectively interrupted the process of succession. It was more difficult to control the aggressive herbaceous plants mentioned above. The grazing of the lot involves trampling by the animals causing physical damage and compaction of the soil probably aggravated by periodic bouts of overgrazing in a pasture of declining productivity. All of the factors together -- weed control, frequent use of fire, and physical damage to the soil by grazing -- act to impede the recolonization of the lot by native vegetation leaving the lot more susceptible to invasion by aggressive pasture weeds and slowing down the period of natural recovery of the lot. The farmer ends up with a degraded pasture, which upon abandonment, takes considerably longer to recover its native fertility. This is what I term a "degraded purma."

What happened upon clearing and burning of the lot on Farm 4 and our attempt to establish pastures there? The farmer did not help us with his management of the clearing and burning process. The clearing was carried out in the final two weeks of August and upon completing the clearing process, the farmer fired the field the next day, without allowing the cut slash to properly dry out. Needless to say, the burn was less than successful leaving considerable area unburned and failing to convert all of the cut vegetation to nutrient-rich ash. Plants that survived in the unburned areas. together with the seeds stored in the soil, were an effective bank of weeds for recolonization of the lot. The farmer planted maize shortly after burning the lot in the first days of September. The September drought ruined his crop. We waited seven weeks to plant the pasture, in which time the weeds had been growing unimpeded. This necessitated an application of herbicide (glyfosate, commercial name Round-up) prior to sowing.

Figure 10 illustrates the floristic evolution of the lot. Note that at the time of the second evaluation weeds covered 65% of the lot, 21% was bare soil and only 14% pastures. At this point the project intervened in the process providing assistance in weed control to the farmer. We provided more Round-up and some hand labor to aid the farmer in weed control. A little more than one gallon of Round-up was applied over 2 has (in addition to the pre-planting application of one gallon) and 39 man days of labor used in weed control (the project providing 5 man days). We also took the decision to abandon a portion of the lot (about 15-20% of the total area) characterized by poor drainage where the pastures have established poorly and were being overgrown by weeds. Subsequent evaluations do not take this poorly drained area into account, therefore Figure 10 gives a slightly biased view of the establishment process.

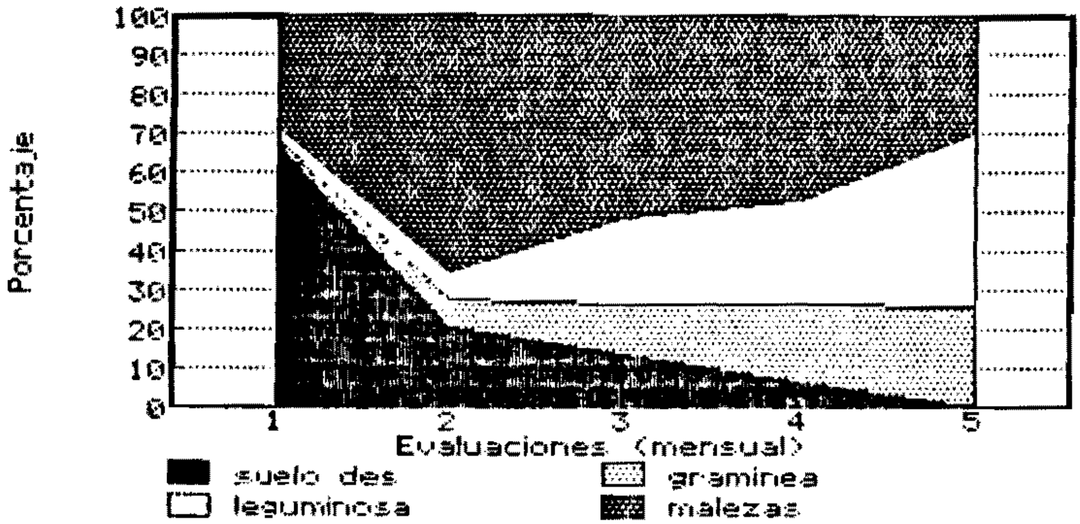


Figure 10. Rate of pasture establishment, Farm 4

This was the only lot in which we had to intervene so strongly to establish the planted pasture. The cost of weed control was about US$ 100.00 per hectare, equally divided between herbicide and hand labor. At the end of the establishment period the legumes were allowed to flower and set seed. The farmer then grazed the lot and burned it to control the resurgent weeds. When I last visited the lot in early December it was tremendously overgrown, but there were also considerable amounts of forage present. We have decided to go ahead and initiate controlled grazing of this lot, together with measurements of milk production. We will continue periodic evaluations of botanical composition on this and all the other lots to measure the ability of the planted pastures to compete with weeds.

Several major issues are raised by this case. If it is indeed true that grazing has negative effects on natural recovery, prolonging the fallow cycle, this has important implications for the sustainability of these farming systems. From the farmer's point of view a prolongation of the fallow cycle would endanger the viability of this farming strategy of shifting cultivation with grazing. The farmer is not particularly concerned with deforestation -- deforestation is simply the process of converting wilderness to productive use and the trees simply represent sacks of fertilizer that upon burning will give him a good start at farming. The planting of crops and pastures are not destructive activities, they are income generating agricultural activities. Pastures themselves have the very positive effect of extending the useful life of a given cleared area. Instead of extracting only one or two harvests from a given plot and then abandoning it to fallow, the use of pastures extends the productive life of the clearing for up to five years (under current technology). Pastures also diversify the economic base of the farm. However the farmer depends on the ability of the land to recover its productive capacity in a relatively short time after abandonment using natural processes which cost him nothing aside from the foregone production during the fallow period). This allows the farmer to reinitiate the cropping pattern, harvest annual crops and renew his pastures.

If the hypothesis is correct that the physical effects of grazing, together with the negative impacts of pasture management, cause a lengthening of the fallow period necessary to recover natural levels of fertility, this presents a serious problem for the farmer and threatens the viability of the farming system. At present we do not know to what extent this process is inevitable or how much is it dependent on the pasture species planted and/or the management skills of the farmer. These are questions which merit investigatibn.

3.1.5. Pasture establishment: conclusions

We mentioned at the outset that the project was interested in determining key factors influencing pasture establishment and that there were a number of implicit assumptions regarding what some of these factors might be including biomass and botanical composition prior to clearing and burning, chemical and physical status of the soil and management of the establishment process including the use of appropriate germplasm. What can we say about these factors based on this research.

3.1.5.1. Biomass -- Biomass of accumulated secondary vegetation is clearly linked to the number of years of fallow. However as we have seen the previous land use also has a strong influence on the rate of biomass accumulation and site recovery. In order to investigate more thoroughly the relationship between biomass and pasture establishment it was necessary to have a quantitative measure of the relative success of pasture establishment that could be related to biomass. The previous measures have simply focussed on the relative percentage of various floristic components of the lots without measuring the quantity of forage produced. At the end of the establishment phase a botanical analysis, known as BOTANAL, was carried out. BOTANAL provides an estimate of available forage in kilograms of dry matter per hectare that is separated into planted grasses, planted legumes by species, broad-leafed and narrow-leafed weeds. The results of this analysis are presented in Table 11.

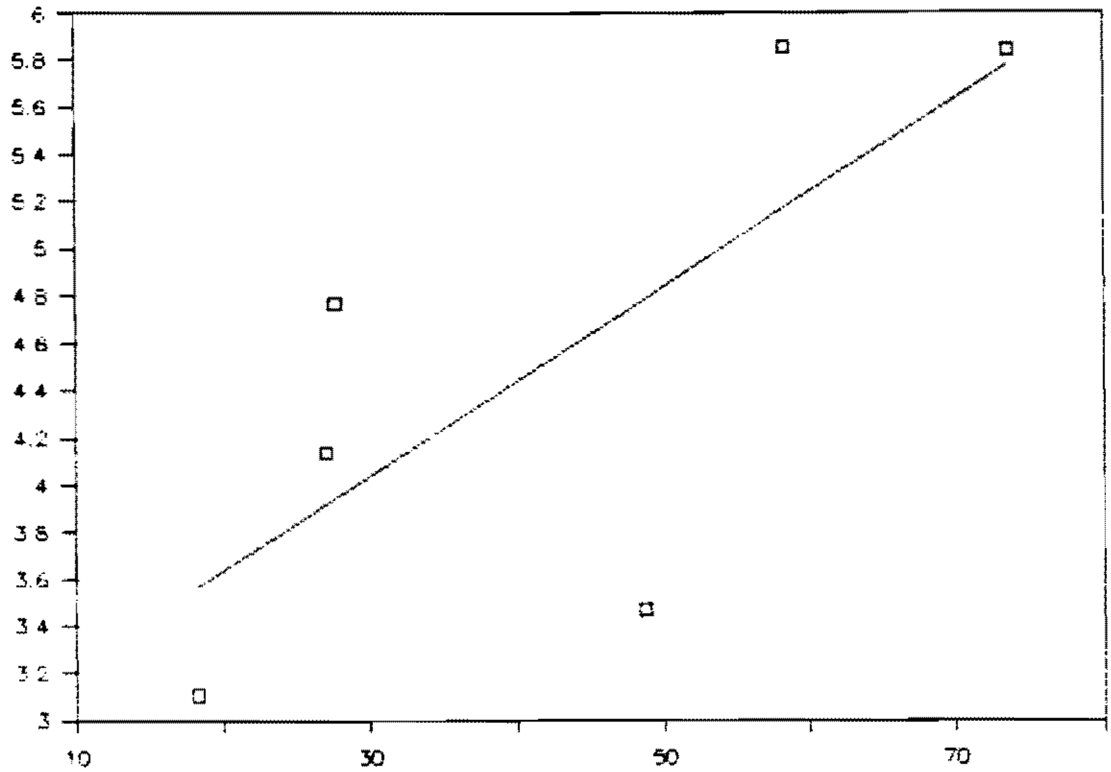
Table 11 presents three sets of data for six of the eight farms where BOTANAL was carried out. (Two farms were eliminated-- numbers 2 and 8 because the forage had been harvested in both cases before the BOTANAL analysis was carried out; on Farm 2 for seed of A. guyanus and on Farm 8 through grazing of the plot.) Table 11 presents information on the biomass of the purma prior to burning, the estimate of total available material (forage plus weeds), and the forage available from the planted pastures. The last column lists planted forage as a percentage of total forage.

Table 11. Purma Biomass and Forage Production on Selected Farms

Farm #	Purma Biomass (kg MS/ha)	Total Forage (kg MS/ha)	Planted Forage (kg MS/ha)	% PF:TF
18,266	6,175	3,106	50	
3	27,680	6,670	4,769	71
4	27,098	6,913	4,134	60
5	48,762	4,300	3,470	81
7	58,426	6,743	5,853	87
10	73,567	8,547	5,838	68

What interests us here is the relationship, if any, between biomass of the purmas and the forage produced. The hypothesis is that there is a positive relationship between purma biomass and resulting forage biomass. Testing this hypothesis is complicated by the different management treatments given the plots during establishment. For example on Farms 1 and 10 the plots were not weeded, and the remaining plots were weeded to varying levels of intensity (Farm 7 investing the most man days per hectare, followed by Farms 4, 5 and 3). With the exception of Farm 4, with the degraded purma and serious weed control problems, there seems to be a relationship between increased labor input weeding and increased proportion of planted species as a percent of the total. Another variable management factor is the presence or absence of a crop. Farm 5 harvested 1,500 kg/ha of maize grains plus an undetermined amount of non-grain dry matter (stalks, etc) which probably affected both total and planted forage production. The harvest represents offtake of dry matter and competition with the maize probably reduced pasture production as well. The variable management treatments obviously have great potential for masking the effect of purma biomass. Logically we would expect weeding to have the effect of decreasing total forage (through the elimination of weedy biomass) slightly favoring planted forage production (through reduction of competition).

**Figure 11. Correlation-Regression --
Purma Biomass and Planted Forage**



Observations:

Farm	X	Y	Expected
1	18,266	3,106	3,566
3	27,680	4,769	3,943
4	27,098	4,134	3,919
5	48,762	3,470	4,787
7	58,426	5,853	5,174
10	73,567	5,838	5,780

Regression Output:

Constant:	2.835
Std Error of Y Est	0.886
R-Squared	0.540
Number of Obs	6
Degrees of Freedom	4
X Coefficient	0.0400
Std Error Coef	0.018

Analysis of Variance

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R Squared
Model	1	3.687	3.687	4.699	0.096	0.54
Error	4	3.138	0.785			

Correlation regression tests were performed with purma biomass as the independent variable and the quantity of total forage and planted forage production as the dependent variables. The relationship between purma biomass and total forage production is not significant. The relationship between purma biomass and planted forage biomass is significant at the .096 level with regression coefficient of .54 indicating that purma biomass accounts for a little over half the variation in planted forage production. (The results of the latter test is presented in Figure 11. Given the number of intervening variables (management, crop production, etc) this result clearly supports the hypothesis that planted forage production is related in a significant way to initial purma biomass.

It is much more difficult to construct straightforward statistical tests of the relationship between soils and forage production and management and forage production. Therefore I will briefly summarize in a subjective way my impression of the importance of other key factors influencing pasture establishment.

3.1.5.2. **History of land use:** As mentioned in the section on biomass, land use history has a clear effect on the rate of accumulation of biomass. While there is a clear relationship between the time of the fallow period and accumulation of biomass, particularly intense or damaging land uses can impede this process of biomass accumulation. As discussed at some length in section 3.1.4 above, grazing, accompanied by vigorous weed control efforts and frequent burning seems to be a particularly damaging form of land use that delays the successional process and impedes rapid biomass accumulation and the suppression of weeds.

3.1.5.3. **Management:** The importance of management to successful pasture establishment is one of the most important conclusions of this work. Management impinges on the pasture establishment process at several points including:

> site selection: given the importance of biomass accumulation and weed suppression in the fallow period and its links to land use history, selection of an appropriate site for crop-pasture production is critical. As the case of Farm 4 illustrates, if a marginal site is chosen it requires a tremendous input of management (i.e. labor) to overcome poor initial conditions;

> timing of agricultural activities: another key element of management is timing agricultural activities to seasonal climatic variation. Staring with clearing and leading up most critically to planting, correct timing is essential. Fortunately

the climate of this area and the humid tropics in general is fairly benign but as the loss of several maize crops on experimental plots indicates, annual variation in rainfall is an important factor;

labor input weeding: results form this research illustrate that weeding is an important factor in pasture establishment influencing the total planted forage produced and the timing of initial grazing. Farmers currently view fire as an alternative management strategy to hand weeding but this strategy extends the length of the establishment phase and may have other deleterious agroecological effects such as volatization of nutrients. Fire is also detrimental to legume persistence. The importance of weeding varies with the initial site conditions with shorter fallows (lower biomass, greater weed content) needing more weeding.

A general rule of thumb regarding management is that its importance increases with a decrease in fallow time. Sites that have had longer to recover from previous land use and have had less intense land use require less management. The converse of this is that to a certain extent management (labor and external inputs) can be substituted for fallow time in the process of reincorporating areas into production.

The importance of management is a significant finding because of the lack of attention it generally receives in agricultural research. The TPP -- and other technologically-oriented research programs -- tend to emphasize germplasm as a panacea to production problems. Yet all technology must be managed properly in order to express its potential. It is easier to release a new cultivar than it is to release management practices. Not only are they often more site specific, the release of management recommendation is essentially an information transfer, rather than the transfer of a tangible good. The transfer of information requires a different set of skills and communication infrastructure than does the release of plant materials. As the TPP succeeds in identifying improved germplasm it will need to focus more on management recommendations and information transfer requirements. The TPP is aware of this; it will be a difficult task none the less.

3.1.5.4. Germplasm: This research also shows the importance of appropriate germplasm to pasture establishment. Germplasm must be evaluated in terms of both the agroecological conditions and the anticipated management. There is no such thing as an "improved pasture" independent of the agroecological and management context. A few examples will suffice. The use of Andropogon guyanus, an upright forage grass, is appropriate in the humid tropics only in situations, such as long fallow cycles, where weeds are not expected to be a serious problem. The use of legumes of the genus Centrosema was generally not satisfactory in the on-farm trials because the planting technique used -- broadcast sowing --is not appropriate for the large-seeded Centrosemas. Centrosemas must be planted 3-5 cms deep in order to germinate properly. Correct management is essential to their success. Finally the use of fire as a management strategy will constrain the type of legumes appropriate for these systems. The legumes must either be fire tolerant and resprout from burned plants (as the grasses do) or seed heavily so they can regenerate from seeds stored in the soil. None of the legumes tested resprouted from burned plants, therefore copious seed production is an important legume attribute.

3.2. Characterization of Production Systems

3.2.1. Introduction

When we refer to farming or production systems we are essentially referring to how the farmer manages a set of technological components given the availability of a series of production factors (land, labor and capital) in response to available information on agroecological conditions, market opportunities and household demands. Farmer management can also be termed the adaptive strategy of the farmer, a term which conveys management as a set of coping behaviors in the face of often changing environmental conditions (Bennett 1976). Adaptive strategies pursued at the individual or group level often have an impact on the prevailing agroecological conditions (natural resources such as soil, water, vegetation, etc), market conditions, or other elements of the environment which in turn demand adjustments in the farmer's adaptive strategies. This dynamic relationship between adaptive strategies and environmental conditions has been termed the adaptive process by Bennett (1976). I find this a useful conceptual framework for examining the behavior of the farmers studied in this research.

There are a number of possible ways to study farmer adaptive strategies. The method chosen in this case was the classic anthropological technique of participant observation and informal interviews, supplemented by formal surveys and the experiments in pasture establishment carried out on farmers fields. This information will be supplemented by data on milk production currently being gathered. However partial or total budget analyses were not carried out, though such information would complement the current analysis very well. The following attempts to summarize my findings on the nature of production systems particularly in relation to the role of pastures and cattle in the farming system and the issue of environmental degradation. The questions we wish to answer include: Are current systems damaging the resource base in such a way as to imperil the viability of the system? If so. what drives farmers to engage in destructive land use practices?

The first step in understanding adaptive strategies is to understand farmer goals and relate them to the patterns of resource constraints and availability. The principal goal of small to medium producers in the study is similar to those of many market-oriented, resource-poor farmers: to acquire and save sufficient cash reserves for the purchase of goods and services that can not be efficiently produced by the household. The challenge of the Amazonian pioneer farmer is to convert relatively abundant land into income by means of available labor and management skills complemented by the small amounts of cash available to the household.

The strategy chosen to reach this goal must respond to the complex of limiting factors prevalent in the zone including agroecological factors such as acid, infertile soils, biotic pressures, patterns of climatic variation and seasonality and socioeconomic factors such as distance to markets, high transport costs, relatively expensive and scarce labor supplies and scarce and expensive credit. In the recent past widely fluctuating prices and high rates of inflation have also characterized the general economic environment.

In the face of these constraints most farmers have chosen a strategy of diversification of agricultural production to acquire cash and survive uncertainty. (Farming strategies are combined with salaried work when this does not compete excessively with on-farm activities.) Farmers in the Pucallpa region, for example, pursue a variety of agricultural activities such as annual crops, cattle raising and small livestock husbandry with a strategy of minimum management and investment in any single activity. No single agricultural activity is perceived to have such a clear-cut advantage in terms of profitability, income stability or risk avoidance to enable farmers to specialize at the household level.

Diversification is a response to the lack of one particular system of production that is highly profitable and secure in relation to other technological options. This explains why farmers remain interested in the production of basic food crops in addition to livestock. The production of crops such as yuca, plantains, maize and rice is a key household survival strategy as it reduces dependence on a volatile external market. These products are used for home consumption, to feed barnyard animals which are in turn consumed or sold, or sold on the open market when there is a household surplus, when market conditions are favorable or when financial need dictates.

Within this system cattle raising represents a source of income and a form of savings that has very low opportunity costs in terms of labor input involved in management and land use. Cattle are managed extensively with little cash expenditures for veterinary medicines or dietary supplements. Pasture establishment is combined with crop production to extend the productive life of already cleared areas. The low marginal costs of pasture establishment when combined with crops explains why small to medium producers rarely clear land for exclusively for pasture but at the same time may plant pasture even when they lack animals to consume the forage.

Small to medium farmers in the study area are sensitive to changes in technology and opportunities in the market and change their adaptive strategies in response to new opportunities. For example, the role of cattle in these production systems changes with the possibility of marketing fluid milk on a regular basis. Under these conditions cattle raising changes from a low cost form of savings to a daily source of income. However this opportunity requires changes in the pattern of labor allocation on the farm and increased management costs in terms of time, labor and purchased inputs needed to maintain the productivity and health of the herd. At this point the farmer must make a calculation regarding the benefits of engaging in milk production versus its cash costs and the cost of foregone income from other, neglected activities. This is what is occurring in the Pucallpa region today, spurred by the availability of Pucallpa as an urban market and a development project that initiated collection and marketing of milk on a daily basis.

In spite of the growing importance of cattle within systems of dual production in my opinion we are still far from the point at which the small to medium producer can rely completely on either the beef or milk production to the exclusion of other economic activities such as crop production. This is due in part to low animal productivity which the TPP's technology can partially solve, but also due to the rather precarious links to the market and widely fluctuating prices for milk and meat.

In addition the small to medium producer is interested in crops as a means of reducing the costs of pasture establishment. There are important complementarities between crop and pasture production. The system also evolves over the life of the farm enterprise. Initially pastures and cattle are a secondary component within the system, when the farmer may have a small herd and abundant uncleared land to cultivate. As the herd increases and the productivity of the land for crop production decreases, cattle and pastures grow in importance.

However this changing pattern of production may carry the seeds of its own demise, linked to the process of land degradation mentioned in the previous section. It was argued above that the grazing of cattle in the Amazon under management regimes typical of the region (overgrazing, frequent use of fire, elimination of secondary vegetation) and in pastures typical of the region, degrades the land and inhibits the restorative processes of natural bush fallow (an observation made in Brazil by Uhl, Buschbacher and Serrao, in press).

This process of land degradation lowers the productivity of the pasture at the same time that it extends the length of the fallow period necessary for land recovery. This restricts the ability of the farmer to reinitiate the process of sowing crops (for income, household consumption, etc) and renovation of pasture to maintain animal productivity. Eventually the farmer looses the option of expanding onto uncultivated lands for the sowing of crops and pastures (an inevitable result of the process of frontier settlement). If land degradation continues unimpeded a point is reached when all the farm's land is either in pastures in various stages of degradation or in a premature fallow that has not had sufficient time to recover (due to grazing-induced degradation). The farmer confronts a situation where the level of animal productivity supported by the (degraded) pasture is insufficient for household survival and no land is ready for crop cultivation/pasture renovation.

The technical solution to this problem is to reclaim the degraded pastures. At present this involves the use of tractors to restore the structure of the soil and the addition of fertilizer to replace nutrients lost or harvested. This process of reclamation represents a new agricultural activity and cost of production. What was before a "free good" -- the natural process of fallow and land recovery -- is now a capital and management intensive activity dependent on external inputs (machinery and agrochemicals) beyond the economic reach of a small to medium producer.

This fundamental weakness of current production systems is leading inevitably toward an economic crisis and is one of the factors behind the ecological crisis of deforestation and land degradation. The economic crisis is expressed at the farm level by the closing of the option of crop production and the "ganaderizacion" (literally the "cattle-ization") of the farm --the near-exclusive dependence on cattle for income. The farmer ends up surrounded by degraded pastures and insufficiently rested degraded fallows -- a virtual "green-desert" that marks the end of the viability of the production system.

The question naturally arises: If grazing is the cause of degradation, why don't we eliminate cattle from the system? Because of the agroecological constraints of the Amazon exclusive reliance on annual crops is not a viable option. To do so simply represents the continuation of traditional systems of shifting agriculture which in itself is of low productivity and only viable at low population densities. The inclusion of a high value perennial crop is obviously an attractive option but we have few current examples that are both sufficiently productive and legal. Clearly research should continue on possible alternative crops for small to medium producers in the Amazon. However the same environmental and economic constraints that lead a farmer to maintain a diverse production system in the first place also are conducive to the inclusion of livestock in the system.

If we assume that the small to medium producers are a desirable component of Amazonian colonization -- and there are strong social arguments in favor of this strategy -- then the solution of the "degradation crisis" is an urgent necessity. We need to design systems that do not degrade and we need to create techniques to reclaim already degraded areas that are agronomically sound, economically viable and within the financial and technical capacity of the small to medium producer.

3.2.2. Solving the problem of Degradation

We have seen that cattle are an indispensable component of small to medium farms of settlers who have colonized the Amazon Basin. (what is true for Pucallpa seems to also be true in other parts of the Peruvian selva, in Ecuador and Colombia.) At the same time it appears that cattle grazing as currently practiced is a damaging land use. Resolving this dilemma requires a two track research effort: on the one hand we need to create new production systems that do not degrade the natural resource base, and; on the other hand we need low cost, low input techniques to reclaim already degraded lands.

3.2.2.1. Designing systems that avoid degradation

There are two approaches to avoiding pasture degradation. One is to look for forage species that are so aggressive and well- adapted that they persist virtually forever -- which in the current context one might define as ten years or more. If we follow this strategy we are gradually converting mixed production systems to small cattle raising systems. As the farmers proceed with the sowing of pastures they convert their farms into a series of paddocks for cattle grazing. Aside from the difficult technical obstacles to this goal, for various reasons mentioned above I think farmers would prefer to maintain diverse production strategies. Therefore this is not the best option.

The other alternative is to improve elements of existing technological components within mixed production systems in order to raise their productivity and reduce degradation. In this case we should not be looking for pasture species that persisted "forever." Instead we would be looking for highly productive pastures with a certain degree of persistence that do not exhaust the land. In this case it is not only certain germplasm we are looking for rather it is a complex of improved species together with <u>management</u> that avoids degradation.

As we have seen, degradation has various components: it begins with loss of soil nutrients that is linked to loss of pasture vigor and subsequent weed invasion, overgrazing and soil compaction. The key to success is to establish a pasture that efficiently captures and recycles soil nutrients maintaining a closed nutrient cycle and preserving soil fertility and the vigor of the sward. If soil fertility can be maintained without the import of nutrients from outside the system (which the farmer many times will not use), we have solved to a great extent the loss of plant vigor and weed invasion that initiates the degradation process. The forage species we plant must be palatable and productive and capable of competing against the heavy weed competition that is to be expected in most circumstances in this environment. And most importantly, the pasture must be capable of rotating back into a cropping cycle with a minimum of fallow time when the farmer faces the necessity of producing food crops for home consumption or the local market. What we are looking for is a technologically efficient system which uses minimum purchased inputs within the financial reach of the small to medium farmer and which demands minimum changes in his system of management.

Given the constraints of minimum inputs and minimum changes in management the following model of mixed crop-livestock production is one alternative with high probability of adoption by recently arrived settlers in the Amazon Basin. The model is illustrated in Figure 12. Figure 12 has five illustrations representing various stages in the cropping cycle. T-0 represents the beginning of the cropping cycle which is based upon the cutting and burning of a well-rested fallow with high biomass and low weed content. (It might also begin with primary forest but this is not necessary.) The need to avoid the use of purchased fertilizers requires the cutting and burning of vegetation to obtain the nutrients and other beneficial effects of the burn. This of course fits in well with existing agricultural practices that also begin with clearing and burning.

Similar to existing systems clearing and burning are followed by the sowing of annual crops (T-1), the most common in the Pucallpa region is maize, but it could be rice or another crop. Pastures are sown together with the crop. In this case the system requires a pasture grass well-adapted to the edaphic conditions of the region such as <u>Brachiaria decumbens</u>, a species widely used at present, or if biotic pressures increase significantly against <u>B. decumbens</u> (as has occurred in Brazil) there are other alternatives such as <u>B. dictyoneura</u>, <u>B. humidicola</u>, <u>B. brizantha</u>, or <u>Andropogon guyanus</u>. All are grasses with low fertility requirements and adapted to the biotic and abiotic conditions of the humid tropics.

The other critical element of the pasture is the inclusion of forage legumes in association with the grasses. The legumes fix nitrogen from the atmosphere helping to maintain the fertility of the soil and the vigor and nutritional value of the grasses. The legumes also add protein to the animals diet through direct

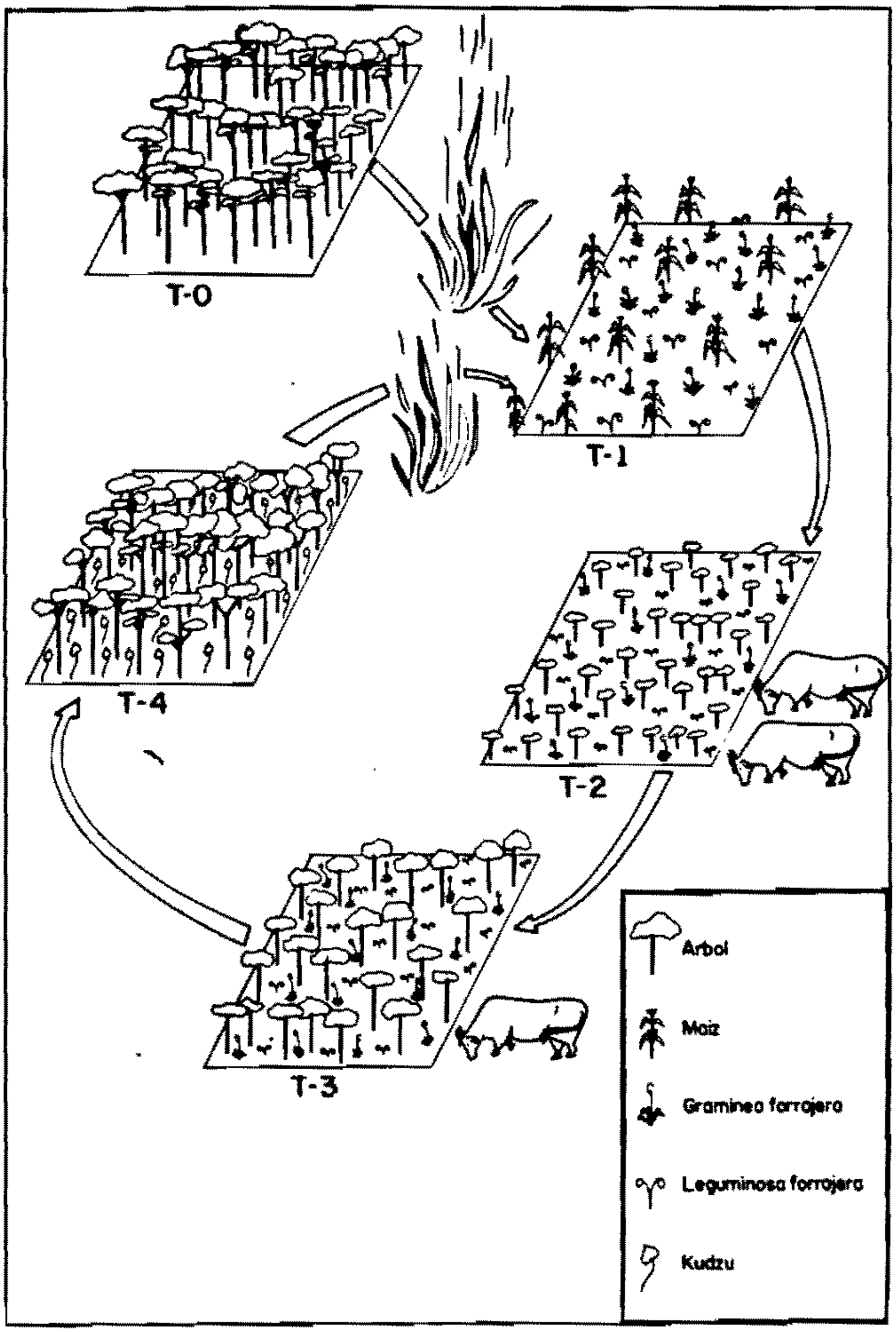


Figure 12. Model of a sustainable agro-silvo-pastoral system

consumption. At present the TPP is experimenting with and promoting the release of various tropical forage legumes such as Desmodium ovalifolium, Stylosanthes guianensis, Arachis pintoi, and various members of the Centrosema genus.

Up to the present we are well within the research philosophy of the TPP. And the only novelty for the producer is the inclusion of legumes. At the end of the crop cycle the product is harvested and the pasture remains in place.

In the subsequent phase (T-2) the grass-legume pasture is established and goes under grazing. The goal here is for T-2 to last four years and to graze the area at two animal units per hectare during this time. Two management modifications are introduced. First the farmer must avoid burning the pasture for its entire useful life -- about six years. The current practice is to burn the pasture at the end of the establishment phase and periodically thereafter to control weeds, initiate tender regrowth by the grasses and (according to the farmers) control ectoparasites such as ticks. Periodic burning must be eliminated in this system to protect the legumes and because of the inclusion of a tree component in the pasture. More research needs to be done on the efficacy and effects of periodic burning to confirm or deny the hypotheses of the farmers regarding its putative beneficial effects.

The other management change is that the farmer allows a certain number of trees to resprout from the original vegetation. Allowing natural regeneration of trees brings several beneficial effects. The deep and well-established tree roots reach into the subsoil acting as nutrient pumps to draw into the system nutrients that would escape the herbaceous pasture species and add them to the natural nutrient cycling process. Recent investigation of pioneer vegetation in the humid tropics indicates that these species are extremely efficient at capturing limited nutrients. This is due to genetic factors and their ability to enter into active symbiosis with soil microorganisms (micorryza) that increase the efficiency of nutrient uptake (Valdés 1988). In addition trees help to reduce soil compaction through their network of superficial roots that maintain soil structure.

The system requires an optimum number of trees -- sufficient to provide the beneficial effects cited above without competing excessively for light and nutrients with the planted pastures. Experiments carried out in the Ecuadorian Amazon by Peck and Bishop (see Bishop 1982) on natural regeneration indicate that 100 trees per hectare (one every 10 mts) is close to the optimum. This requires more research to adjust the number of trees to varying climatic and edaphic conditions.

In addition it may be that the trees allowed to resprout have some commercial value such as bolaina (Guazuma crinita, G. ulimfolia) or huamansamana (Jacaranda copaii) that will contribute to the long-term economic viability of the system. But it should be emphasized that the economic viability of the model does not demand any commercial value for the trees. The trees serve certain functions to avoid degradation within the system (at no cost to the farmer) and begin the process of controlled fallowing essential to the success of the system. In addition, the farmer is not required to plant any trees. The trees enter into the system through natural regeneration; an important point given the difficulty of organizing widespread multiplication of tree germplasm and the difficulty in convincing farmers to devote scarce labor to tree planting.

T-3 in Figure 12 represents the next stage in the crop-pasture cycle. At this point the pasture is entering into its fifth year of grazing. The trees have grown to five or more meters in height and their shade is probably reducing the vigor of the pasture--especially the grasses. The carrying capacity of the pasture should be reduced to one animal unit per hectare. The model assumes that the pasture will be able to support this intensity of grazing for two years without entering into a process of degradation. In both cycles, this and the previous one, the pastures require weeding once or twice a year with a labor input of from 9-18 man hours per year depending on the severity of weed competition. This is not out of line with current agricultural practices.

T-4 represents the next stage and one that is critical for the success of the model -- that of the managed fallow. At this point, after six years of grazing, the farmer abandons the lot and allows it to rest and be recolonized by native vegetation. It might be desirable or necessary to oversow kudzu (Pueraria phaseoloides) or another aggressive legume that covers the soil and is capable of fixing significant quantities of nitrogen to speed the recovery of soil fertility and the suppression of weeds. The Instituto Nacional de Investigacion Agricola y Agroindustrial (INIAA -- the Peruvian national agricultural research institute) in conjunction with the Tropical Soils program of North Carolina State University has been conducting experiments in the use of legumes for managed fallows in Yurimaguas, Peru. While this work is ongoing, one result to date is that when kudzu is used as a planted fallow, it can be cleared and burned after two years and produce 80% of the agricultural yield of a natural fallow of 25 years (Bandy and Sanchez 1985).

In this model we are not starting the fallow period with a clear field whose fertility has been reduced by cultivation of annual crops. The trees and forage legumes have maintained soil nutrient levels and accumulated significant amounts of biomass. Therefore it is not unrealistic to expect that two years of fallow will be sufficient to restore fertility.[1] After two years of fallow the vegetation is cleared and burned. If there are commercially valuable species within the purma, they would be harvested at this time without reducing the restorative function of the fallow. After clearing and burning the cycle begins again with T-1.

This model is designed to avoid the degrading effects of grazing through better germplasm and management, thereby avoiding the prolongation of the fallow period. In fact through the inclusion of nitrogen-fixing legumes, together with native trees, it is hoped to significantly reduce the fallow period necessary to restore soil fertility and structure and suppress weeds. Still the question arises: how much land is necessary for the stable functioning of this system?

To answer this question the evolution of this system was simulated for a 50 hectare lot over a 25 year time span. The results of this simulation are presented in Tables 12 and 13. Table 12 represents the first twelve years of production in a typical 50 ha farm. One hectare is subtracted for house, installations and family garden and orchard. The model assumes that a farmer is capable of cultivating about 5 hectares of land per year using traditional technology and slash and burn techniques. Column 1 in Table 12 indicates the year of farm activities starting with year 1 and continuing until the farmer has worked all of his original vegetation -- a period of ten years. The second column shows the total carrying capacity in animal units together with the cumulative number of hectares in pasture over a twelve year period. We can see that carrying capacity peaks at 58 animals on 34 hectares of pasture in year 11. The series of columns marked 1-12 illustrates the stage of the agricultural cycle of each of the five hectare lots over the twelve year period.

To measure the sustainability of the system over a longer time period the same analysis was extended over a 25 year period (Table 13). The first column of Table 13 shows the hectares and carrying capacity of the pasture from years 1-10 and the second shows the same information for years 11-20. The columns marked 1-25 show the stage of the agricultural cycle of each five hectare lot over the 25 year span (similar to columns 1-12 in Table 12). Note that after the peak of 58 animals on 34 has of pasture in year 11, the carrying capacity dips to 54 animals on 34 has of pasture in year

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[1] In discussion with members of the TPP some have suggested that with proper management and germplasm it may be possible to eliminate the fallow period altogether and go to a "ley farming" system. This model takes a more conservative view of the possibilities for intensification.

ño	Carga Animal	Area en Pastos		ETAPA EN CICLO AGRICOLA 1	2	3	4	5	6	7	8	9	10	11	12
			1 ha												
1	0	0	5 has	T1	T2	T2	T2	T2	T3	T3	T4	T4	T1	T2	T2
2	10	5	5 has		T1	T2	T2	T2	T2	T3	T3	T4	T4	T1	T2
3	20	10	5 has			T1	T2	T2	T2	T2	T3	T3	T4	T4	T1
4	30	15	5 has				T1	T2	T2	T2	T2	T3	T3	T4	T4
5	40	20	5 has					T1	T2	T2	T2	T2	T3	T3	T4
6	45	25	5 has						T1	T2	T2	T2	T2	T3	T3
7	50	30	5 has							T1	T2	T2	T2	T2	T3
8	50	30	5 has								T1	T2	T2	T2	T2
9	50	30	5 has									T1	T2	T2	T2
0	50	30	4 has										T1	T2	T2
1	58	34	50 has												
2	58	34													

Table 12. Simulation of land use patterns of the production model illustrated in Figure 12 during the initial twelve years.

0-10	11-20	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25
0 / 0	58 / 34	T1	T2	T2	T2	T2	T3	T3	T4	T4	T1	2	2	2	2	3	3	4	4	1	2	2	2	2	3	3
10 / 5	58 / 34		T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4	1	2	2	2	2	3
20 / 10	58 / 34			T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4	1	2	2	2	2
30 / 15	58 / 34				T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4	1	2	2	2
40 / 20	54 / 34					T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4	1	2	2
45 / 25	54 / 34						T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4	1	2
50 / 30	50 / 30							T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4	1
50 / 30	50 / 30								T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4	4
50 / 30	50 / 30									T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3	4
50 / 30	58 / 35										T1	T2	2	2	2	3	3	4	4	1	2	2	2	2	3	3

Table 13. Simulation of land use patterns in the production model over a twenty-five year period.

15 and then to 50 animals on 30 has of pasture in years 17-19. In year 20 carrying capacity recuperates to 58 animals and fluctuates between 50 and 58 animals indefinitely in the future.

It is important to point out that in every year 4-5 has of land are available for the sowing of annual crops. Table 12 demonstrates this for the first 12 years and Table 13 illustrates that this is a constant tendency over 25 years and indefinitely into the future. As areas in pasture enter into the fallow cycle other areas enter into production. When the farmer arrives at his last lot of 4 has the first parcel has gone through two years of fallow and is ready to clear and burn for sowing crops. Therefore 50 hectares appears to be the minimum size necessary for the stable functioning of this system. With 50 has of land as the farmer arrives at the end of his purmas (or original forest vegetation) the first parcel is again ready for cultivation. A system of rotation of crops, pastures and fallow is maintained allowing the farmer to have access to crop land every year and maintain a reasonable number of cattle. What we are proposing is a 1-6-2 production cycle: one year of crops, six of pastures and two of managed fallow.

The key to the viability of this system is the ability to shorten the fallow period to only two years through the use of legumes and selective regeneration of trees. At this point managed fallows as proposed here are experimental and unproven. Devoting more research to this topic should be a top priority. The attractiveness of the model is that it closely matches existing production systems which enhances its prospect for adoption.

3.2.2.2. Recovery of Degraded Lands without Mechanization

For farmers with extensive areas of already degraded lands, sizable herds of cattle and without additional uncleared lands (typical of longer term settlers) there is an urgent need to develop inexpensive relatively simple means of recovering degraded lands without the use of scarce and expensive agricultural machinery. The work of CIAT in the area of pasture reclamation to date has focused on the use of tractors with varying combinations of agricultural implements and fertilizers to recover degraded lands. But as we have seen these are not viable options for the small-to-medium producers who are increasingly confronted with the problem of degraded lands.

Perhaps the most practical option for the small-to-medium producer is to substitute time for inputs in the process of land rehabilitation. In most cases the most abundant factor of production for the small-to-medium producer in the Amazon is land.

In spite of the fact that a significant portion of land may be invarying stages of degradation, if intervention is made sufficiently early in the "life cycle" of the farm, the farmer has enough land that a certain amount can be idled for recovery purposes. The basic problem is that the natural process of recovery has failed due to abusive land use (e.g. overgrazing) and some investment on the part of the farmer must be made to more rapidly recover his lands.

Once again the best hope for a simple, non-mechanized method seems to lie in some sort of green manuring process for accelerating the process of natural recovery as was discussed in the previous example. But in the case of already degraded lands we face a more difficult situation: intervention in the process comes after productivity has already "crashed" -- after fertility has declined, soil has been compacted and other degradation processes are underway. The hope is that legumes within the TPP's bank of germplasm -- and perhaps others as yet uncollected -- are sufficiently adapted to low fertility conditions that they can be established and over time come to dominate the existing weedy flora, and eventually contribute to the recovery of these lands.

For this strategy to work the planted fallow must be more efficient than native plants in rehabilitating the soil. The time factor is critical in this process. An economic analysis was carried out on three alternative means of recovering degraded pastures (Toledo, Seré and Loker, n.d.[2]):

<u>Alternative A</u> is the capital intensive means utilizing mechanization and fertilization;

<u>Alternative B</u> relies on natural processes of soil regeneration and weed suppression over a ten year period, and;

<u>Alternative C</u> uses a managed fallow of planted legumes to accelerate the recovery process.

The economic analysis examines expected cash flows over a ten year time period in order to evaluate the economic viability of each method (see Table 14). Some explanation of the figures used is in order. The degraded natural pasture is assumed to produce animal weight gains of 275 grams/animal/day with a carrying capacity of 0.65 animal units/ha generating a net cash income of $32.70/ha/year. The net cost of Alternative A is estimated at $245/ha based on current prices in Pucallpa and experimental data

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[2] The analysis here differs slightly from that presented in Toledo, Sere and Loker due to further refinements in the model.

from the TPP. The costs in labor and seeds to clear, burn and sow a pasture after a ten year fallow period is estimated at $25.50/ha based on data from Pucallpa. And the estimated cost of establishing the managed fallow is $49.00/ha based on best guess estimates of this still-experimental technology. The net capital flows of the three alternatives are presented in Table 14.

Table 14. Comparative costs of alternative methods of pasture reclamation, Pucallpa

	Alternative		
Year	A	B	C
1	32.7	0	32.7
2	32.7	0	32.7
3	32.7	0	32.7
4	32.7	0	32.7
5	32.7	0	32.7
6	32.7	0	32.7
7	32.7	0	-49.0
8	32.7	0	0
9	32.7	0	0
10	-245.0	-25.5	-25.5
Net income	49.3	-25.5	121.7

Source: Modified from Toledo, Seré, Loker, n.d.

Notice that Alternative A has the advantage of producing some income over nine of the ten years before pasture recuperation thereby offsetting the high costs of mechanized pasture recovery in the tenth year. Alternative B requires that the land lay fallow for ten years providing no income during this period. At the end of the tenth year the area is cleared, burned and sown in maize and pastures. However an important difference between the two methods is not revealed in this analysis. The only cash costs of Alternative B are the costs for seeds. Alternative Ahas much higher cash costs; in addition to cost of seed there arecash outlays for fertilizer ($34.85/ha) and machinery ($187.50, based on current hourly rental costs in Pucallpa). Recall that one of the primary goals of the small-to-medium farmer is to capture and save cash to spend on the numerous competing demands for this scarce resource. The farmer is therefore interested in minimizing cash expenditures in farming. Therefore capital-intensive methods are not attractive for these farmers. This obstacle could be overcome through making credit available for pasture reclamation but credit programs generally discriminate against small farmers leading to inequitable distribution of credit in favor of large farmers.

Alternative C represents a compromise between the rapid pasture recovery of Alternative A and the need of small farmers to minimize cash costs. In Alternative C the farmer realizes income for six years then takes the land out of production to initiate a managed fallow. This practice requires the application of herbicide ($25.50/ha), fertilizer ($2.25/ha) and legume seed ($9.00/ha) plus labor. The land must then remain out of production for four years. At the end of the fourth year the area is cleared, burned and sown in maize and pasture in the traditional manner.

The analysis demonstrates a clear advantage of Alternative C when compared to capital intensive and minimum management methods. It would be particularly attractive to farmers who have extensive areas of degraded land and are therefore facing a land constraint. For these farmers removing a given area from production for ten years is not a viable option. In the Pucallpa area we already see small farmers trying to bring very young fallows of two or three years back into production with unfavorable results. These farmers are very open to suggestions for a minimum input means of accelerating the fallow process.

There has been very little experimental work in this area. Once again the Tropical Soils program at Yurimaguas has been experimenting with several legume species for the acceleration of land recovery after annual cropping, with some promising results. But to my knowledge the same type of work has not been done on highly degraded sites after grazing. If the observations in this and other studies are correct regarding the negative impacts of grazing, we are confronting a significantly different and more difficult situation. Perhaps the most important question concerns the effects and duration of structural damage to the soil caused by trampling. This imposes a difficult burden on the germplasm selected: not only must it contribute to the chemical recovery of the soil. it must also rehabilitate the physical structure as well. The TPP is initiating an experiment designed to test various legume species and experimental treatments for the recovery of degraded lands similar to those proposed in Alternative C. Much more needs to be done in this area.

3.2.2.3. Conclusions and Research Needs

Analysis of production systems and their ecological context from the point of view of farmer adaptive strategies and adaptive processes gives new insight into why farmers engage in land uses that damage the resource base. To a certain extent this represents a technical problem: there are a lack of suitable technological options for sustained production in the humid tropics. The viability of proposed solutions to this problem must fit not only the agroecological constraints of acid infertile soils, etc. but also the socioeconomic constraints of limited capital and labor and existing marketing channels for agricultural products. There are also social organizational constraints to solving these problems such as the lack of organization among small-to-medium farmers to vocalize and press for solutions to their problems. Lack of organization also impedes the delivery of technical knowledge as well as circumscribing the range of possible solutions. For example the lack of organization hinders the introduction of shared agricultural machinery as one possible solution to the individual farmer's lack of capital for purchase of such equipment.

In terms of further research to solve specific technical problems there are two broad lines of investigation needed: one to study the process of land degradation and the other to test possible low cost solutions. Within these two closely related research areas, possible priorities include:

1) detailed study of the process of degradation to determine more precisely the role of biotic and abiotic factors and the role of germplasm vs management in the process of land degradation with the goal of discovering the most effective ways of avoiding it, particularly important is the role of compaction and structural changes in the soil in contributing to degradation and the process of weed invasion;

2) study of patterns in vegetation succession and the process natural soil recovery to determine key factors that affect this process, the mechanics of vegetation colonization, the mechanisms for nutrient capture and recycling by pioneer species, edaphic processes in site recovery, etc with the goal of designing effective interventions in the fallow process to shorten the recovery period necessary;

3) study the possible commercial uses of common pioneer tree species, including their value as forage, (studies already initiated in Peru) and the environmental factors affecting the botanical composition of bush fallows;

4) study management criteria used by farmers in order to understand the reasons for some problematic aspects of management such as frequent use of fire, overgrazing, etc;

5) study the role of trees in pastures to confirm their role in the efficient uptake and recycling of nutrients and in protecting soil structure, as well as studying aspects of competition between trees and tropical forages to assess the feasibility of the inclusion of trees within pastures and determine optimal tree densities under varying climatic and edaphic conditions;

6) study the possible uses of legumes in accelerating the process of land recovery and rehabilitation determining which species are most appropriate and optimum management strategies;

7) economic studies of the costs and benefits of various production schemes (including the agro-silvo-pastoral model described here) and the profitability of various methods for the recovery of degraded lands to determine their potential for adoption under varying input:output ratios.

The exact nature of the experiments for this research must be determined by the scientists involved. However it is important that both basic and applied research recognize the nature of the constraints and goals of small and medium farmers in the Amazon in order to generate useful results as quickly as possible.

3.3 Other Research Activities

3.3.1. Artisanal seed production

Interest in artisanal, or small-scale, seed production stems from the need for a short term solution to limited supplies of improved grass and forage legume seeds. Lack of seed limits experimental work that demands sizeable quantities of seed, such as multilocational grazing trials and on-farm research, and impedes initial technology adoption in early stages before a secure market for the seed has been established and commercial seed production begins. Because of limited seed supply and also to stimulate interest in Pucallpa in on-farm seed production among national research institutions, a seed multiplication component was built-in to my research.

The project was fortunate that some experimental stands of one of the forage legumes species (Stylosanthes guianensis) had been established on farms both through voluntary action by farmers and as part of a technology transfer effort made by IVITA three years earlier. Unfortunately the IVITA work was discontinued and never followed-up when funding for their project was cut. However some farmers had maintained their plots of Stylo; it was one of these plots that was harvested in July 1987.

This effort was the first commercial contract for the harvest of tropical forage legumes between CIAT and a small farmer in the humid tropics. Table 15 illustrates the structure of costs associated with the harvest. As can be seen, overall the operation resulted in significant profit for the farmer; approximately I/10,650 or about US$305.00 from less than one hectare of land.

Table 15. Costs Associated with the Harvest of Stylosanthes guianensis on the farm of Pedro Cabrera

Task	Man days/Cost		Equipment/Cost	
Cut and Stack	35	3,500	tarps sickles	2,350 200
Threshing	14	1,400		
Cleaning Seed	12	1,200	screens	2,900
Transportation	2	200		
TOTAL	63	6,300		5,450

TOTAL COSTS	....	11,750
YIELD	56 KGS @ I/ 400 =	22,400
PROFIT	....	10,650

Costs in Intis, 8/87 (US$1.00 = I/35.00)

Because the harvest was carried out on an already established stand of Stylo it did not answer all the questions regarding the feasibility of producing legume seed on farms; establishment costs were not included. It was therefore decided to plant two small seed multiplication plots (.33 and .25 ha) in collaboration with farmers on their fields in late 1987 for harvest in 1988. The management techniques employed in the two plots were varied. The .33 ha plot was sown according to CIAT TPP Seed Unit guidelines: there was no companion planting, the seed crop was planted in rows, fertilized and received two weedings. The smaller plot was intercropped with rice, sown broadcast, received no fertilizer and one light weeding.

The plots were harvested in July 1988. Table 16 presents a comparative economic analysis of the costs and production of the two plots with Plot 1 representing the higher input option and Plot 2 the minimum input option. Note that although yield was much lower on the smaller, intercropped plot, so were labor input and other costs. If all cash costs are charged to this first year's production, Plot 1 has slightly lower costs per kilogram of seed produced but lower profit per unit of labor. If costs of the durable capital goods -- tarps, sickles and screens for cleaning seed -- are depreciated over their expected five year life span then Plot 2 produces seed at a lower cost per kilogram and extends the advantage in net income per unit labor.

The comparison is not entirely fair as the two plots were quite different from the outset --with the larger plot sown in a 6 year bush fallow and the smaller plot sown in cut primary forest. Also the crop year was atypical with the farmer of the smaller plot loosing most of his rice crop to drought thereby <u>not</u> further reducing his costs through harvest of the grain. It should also be noted that now that the plots are established they can continue to be harvested with no additional establishment costs, lowering significantly the costs of production. The relatively high labor input in harvesting is a disadvantage in farming systems like those under study in which labor, not land, is limiting. But fortunately the harvest occurs during a slack period in labor demand, avoiding conflict with other essential farming activities.

Despite the data's limitations, the results are instructive and suggest that in order to justify the costs of additional inputs desired for forage seed production a companion crop such as rice or maize which would produce a marketable harvest (in most years) would aid in reducing costs. The experience also suggests that artisanal seed production of <u>Stylosanthes guianensis</u> is feasible at early stages in the seed multiplication process before commercial growers become involved provided that the following conditions are met: technical assistance is provided to farmers in planting and harvesting techniques, credit is available for the purchase of capital goods necessary for establishment and harvest operations, and a market with a fair price for seed purchase is guaranteed.

Table 16. Comparative Costs of Seed Production:
Stylosanthes guianensis in on-farm trials-- Pucallpa

Activity	Plot # 1 (.33 ha) Man Days	Plot # 2 (.25 ha) Man Days
Establishment:		
Clearing:	6	0 (rice field)
Remove unburned logs	3 + I/500.00 rent a chainsaw	0
Sowing	5.5 (in rows)	.5 (broadcast)
Weeding	10.5 (Dec-Jan with resowing) 10 (May)	2
Harvest:		
Cut and Stack	18	6
Thresh	7	3
Seed cleaning	6	1
TOTAL	69 x $2.50 = $172.50	12.5 x $2.50 = $31.25
Cash Costs		
Fertilizers	I/588.75	
Insecticide	17.50	
Rent Chainsaw	500.00	
Tarps, Sickles & screens	2,725.00	1,819.00
TOTAL I/	3,831.25 / 42 = $91.22	1,819.00 / 42 = $43.31
TOTAL COSTS	$263.72	$ 74.56
YIELD	28 kgs (=84 kg/ha)	6.8 kgs (=27 kg/ha)

Table 16. Comparative Costs of Seed Production
Stylosanthes guianensis **in on-farm trials -- Pucallpa (cont'd)**

	Plot # 1	Plot # 2
YIELD	28 kgs (=84 kg/ha)	6.8 kgs (=27 kg/ha)
TOTAL COSTS/KG	$263.72 / 28 = $9.42	74.56 / 6.8 = $10.96
<u>Adjusted Cash Costs</u>		
Tarps, sickles & screens, Depreciated over 5 yrs	2,725.00 / 5 = 545	1,819.00 / 5 = 363.80
Fertilizers	I/588.75	
Insecticide	17.50	
Rent Chainsaw	500.00	
Tarps, Sickles & screens	545.00	363.80
<u>TOTAL</u>	I/ 1,651.25= $ 39.31	363.80= $8.66
Labor + Adj. Cash Costs/kg	211.81 / 28 =$ 7.56	39.91 / 6.8 = $ 5.96
Profit assuming price of @ I/1,500/kg	28 x 1,500=42,000	6.8 x 1,500=10,200
Gross Income	42,000	10,200
- Total Cash Costs	- 3,831	-1,819
Net Income	I/ 38,169	8,381
Net Income / Man Day	38,169 / 73 =I/ <u>523</u>	8,381 / 12.5 =I/ <u>670</u>
Gross Income	42,000	10,200
- Adj Cash Costs	-1,651	- 364
Adj Net Income	40,349	9,836
Adj Net Income / Man Day	40,349 / 73 =I/ <u>552</u>	9,836 / 12.5 =I/ <u>787</u>

3.3.2. Legume inoculation on-farm

At the time of sowing grass-legume pastures it was decided to sow one half of the study plot with seed inoculated with the appropriate Rhizobium strain recommended by the program microbiologist. The other half of the plot was sown with no inoculation. The hypothesis tested was that inoculation would increase significantly the quantity of legume in the field. During the establishment phase data on botanical composition were recorded separately for inoculated and non-inoculated treatments. At the end of the establishment period the amount of legume in the two treatments was analyzed using an Analysis of Variance (see Table 17). Percentage of legume in inoculated vs noninoculated treatments is listed in Table 17. Percentages were converted to logs for the purpose of the analysis. The ANOVA test indicates that the difference in amount of legume between treatments is significant at the .02 level. While the data on biological yield are interesting this result does not answer the question of whether legume inoculation has a significant impact on economic yield and is therefore justified at the farm level.

4. Conclusions

The goals of this research were to test a series of hypotheses regarding the adaptation of improved pastures to the abiotic, biotic and management conditions prevailing on farmers' fields and to study their potential for adoption within the context of existing farming systems. In order to study the adaptation of pastures to on-farm environmental conditions, a series of experiments were mounted on farmers fields in close collaboration with farmers in pasture planting and management.
The experiments revealed significant differences among the species tested in terms of their ability to establish readily under farmer management. As ease of establishment under the minimum management strategy pursued by farmers is an important criterion for the adoption of these species, the variable success of the species bears review:

* <u>Brachiaria decumbens</u>: established easily and rapidly under farmer management; establishment per se is not a barrier to adoption, however seed quality has proved to be quite problematic in the past which has caused some skepticism among farmers for the use of botanical seed.

Table 17. ANOVA comparing presence of legumes in inoculated vs non-inoculated treatments.

Farm #	% Legume + Inoc	% Legume - Inoc
1	45	34
2	63	47
3	24	33
4	55	35
5	87	61
7	59	61
8	12	7
12	65	48
13	32	24

	N	Mean	S.D.	Min	Max
% Legume +I	9	49.11	23.27	12	87
% Legume -I	9	38.89	17.46	7	61
Log % Leg +I	9	3.75	.615	2.48	4.46
Log % Leg -I	9	3.51	.663	1.94	4.11

ANOVA Procedure: Log % Legume, +I and -I

Source	DF	Sum of Squares	Mean Square	F Value	Prob > F	R Square
Model	9	6.545	.727	21.36	.0001	.96
Error	8	0.272	.034			

Source	DF	ANOVA SS	F Value	Prob F
Farm	8	6.286	23.08	.0001
Treatment	1	0.259	7.60	.0248

* <u>Brachiaria dictyoneura</u>: appears to establish less rapidly than <u>B. decumbens</u>, a definite drawback in farmers' eyes. It also suffers from variable seed quality. However farmers on the whole seem to be happy with <u>B. dictyoneura</u> as it displays most of the favorable attributes of <u>B. decumbens</u> and contrary to expectations seems more palatable than <u>B. decumbens</u> under grazing. If it proves to be tolerant of spittlebug infestation it may be a popular alternative to the susceptible <u>B. decumbens</u>.

* <u>Andropogon guyanus</u>: established readily and grew rapidly once established. Its main disadvantages are its upright growth habit that does not exclude weeds, the fact that it tends to dry up after flowering and setting seed and that it may be more sensitive to management than the Brachiarias. However even under adverse conditions (viz. Farm 8) <u>Andropogon</u> has been impressive in terms of its persistence and its ability to resprout vigorously after burning. Clearly it is a possible alternative to the spittle bug-susceptible Brachiarias.

* <u>Stylosanthes guianensis</u>: this forage legume performed exceptionally well during the establishment phase. It establishes readily when sown broadcast, grows rapidly and seems to compete well with weeds. Perhaps its greatest advantage is its ability to seed readily and heavily providing a ready source of seed for harvest and resowing and new plants after burning (whether accidental or intentional). In no case were parent plants of Stylo observed to survive burning. Questions remain regarding Stylo's persistence under grazing in association with aggressive grasses such as the Brachiarias.

* <u>Desmodium ovalifolium</u>: This forage legume has a well-deserved reputation for slow establishment. In the on-farm trials it was never prominent in the associations (it never exceeded 10% of the botanical composition). However it is shade tolerant and supposedly persistent so from its reduced presence in the pastures, it may increase over time. It proved sensitive to fire and was not observed to re-establish prolifically from seed after burning like <u>S. guianensis</u>. Continued monitoring of these experiments should determine whether <u>D. ovalifolium</u> is persistent under farmer management. Further experimentation with this species is warranted, but it did not have outstanding performance in this series of experiments.

* Centrosema spp.: The various Centrosema species planted will be treated as a group as they shared one outstanding limitation: they do not establish well when sown broadcast. The seeds must be buried 3-5 cms deep for successful germination. This means additional labor input for planting with machete or digging stick -- a clear drawback from the farmer's perspective as sowing with digging stick involves about 4-8 man days per hectare (depending on plant density) while broadcast sowing requires less than .5 man days per hectare. Even when areas were replanted with Centrosemas using a dibble, growth and vigor were not exceptional. Given the discrepancy between on-station results, were Centrosemas have been outstanding, and the rather disappointing on-farm results, more research regarding variables affecting establishment and vigor on-farm is warranted.

* Pueraria phaseoloides: Though kudzu was not one of the improved pastures under review it merits consideration due to its spontaneous appearance in several of the pastures. Kudzu is naturalized in the region -- a good sign as it indicates that it is well-adapted to environmental conditions. Farmers have experience with kudzu and opinions are divided regarding its palatability, persistence and other attributes. Studying kudzu, and farmer management and attitudes toward this plant, would probably give valuable insights into the future of forage legumes in these systems. If the variables affecting the successful management of kudzu can be determined, this will probably provide insight into the management factors affecting the successful use of other legumes. If kudzu, a well-adapted legume, does not persist under farmer management the same may be true of other legumes.

The research pursued over the past two years has provided valuable feedback to the TPP regarding factors affecting adaptability and potential adoption of improved pasture species, especially forage legumes. One of the most important insights provided by this research is that farmers use different criteria for selecting pastures than those chosen by the TPP for evaluating germplasm. The TPP emphasizes total dry matter productivity as its most important criterion for measuring successful adaptation. (Dry matter production is not the sole criterion, but the most important.) Farmers are more interested in ease of establishment, rapid establishment, ability to compete with weeds and fire tolerance as successful forage attributes. These qualities contribute to ease of management and persistence. These are criteria that need to be systematically included in the agronomic evaluations performed by the TPP. These needs have been communicated to the TPP in a series of quarterly reports, special communications and discussions in Program-wide reviews and will presumably be acted on in the future.

Another key finding of this research has been to raise new questions regarding the relationship between cattle raising -- and grazing in particular -- and land degradation. The findings regarding the effects of grazing on delaying land recovery during the fallow period need to be examined carefully by the TPP in designing strategies to cope with degradation. The impact of grazing on prolonging the fallow period is probably the most serious aspect of land degradation from the perspective of the small-to-medium farmer in the Amazon. Until this process is better understood and practical solutions offered -- through improved germplasm and better management practices -- the viability of small-to-medium farming units is in question.

Finally this research draws attention, if only indirectly, to the important differences between small-scale farming systems and extensive ranches in the Amazon basin. The difficulties in farming this environment underline the need for sensitive management finely tuned to environmental variation to avoid wholesale degradation. Large scale ranching enterprises magnify the disturbances caused to the environment and their short term profit orientation and speculative nature virtually guarantee resource degradation. In contrast, small-to-medium pioneer farmers are more likely to explore, understand and adapt appropriately to spatial and temporal agroecological variation. The desire of these farmers to build equity and pass on a viable farming operation to succeeding generations induces them to husband more carefully the natural resources upon which their livliehood depends. The prerequisite for such behavior is an agronomically and economically sound technological basis for highly productive, sustained yield agriculture. Present farming systems lack certain components to achieve this goal.

The other principal limitation of small-to-medium farmers in the Amazon is an organizational basis for receiving and utilizing improved technology. At present these farmers are at a competitive disadvantage in the struggle for credit and other bureaucratic services at the local and national level. This lack of organization also makes it difficult for them to communicate their needs researchers and to advocate for the solution of their problems. On-farm research with this group of farmers can aid in the identification of technological constraints. Remedying the lack of organizational structures to receive and communicate these advances is a critical and as yet unmet challenge.