Intensified Small-scale Livestock Systems in the Western Brazilian Amazon

7

Stephen A. Vosti, Chantal Line Carpentier, Julie Witcover and Judson F. Valentim

1. Introduction[1]

> It is increasingly clear that economic alternatives [to traditional pasture systems] need to be provided. One option is to provide credit and technical assistance to make better use of existing pastures . . . studies undertaken . . . suggest that well-managed pastures can produce three times more than the average pasture in the Amazon.
>
> (Translated from *Veja*, 7 April 1999, p. 115)

This chapter examines three basic questions regarding the use of more intensive livestock technologies by small-scale farmers in the western Brazilian Amazon. Are farmers likely to adopt them?[2] Would it help protect the forest if they did? What would the effects on the farmers' welfare be? These issues are fundamental, because many people have come to see intensive cattle ranching as a 'win– win' alternative that can simultaneously remove pressure on huge expanses of the Amazon's forests and improve farmers' well-being. Others look at it as a dangerous endeavour, more likely to favour forest destruction than forest conservation, i.e. intensification of this already widespread production system would actually promote the extensive expansion of the agricultural frontier.

In a 'best-case' scenario, intensification increases incomes and reduces deforestation. In a 'worst-case' scenario, farmers do not adopt more intensive systems and their traditional livestock systems deteriorate over time. Incomes decline and deforestation continues or even accelerates, as farmers clear new land to support their herds. In an 'intermediate case', farmers might adopt more intensive systems and thereby increase their incomes, but also clear

Agricultural Technologies and Tropical Deforestation (eds A. Angelsen and D. Kaimowitz)

more forest. The latter may occur because the new technology makes it more profitable to plant pasture and generates additional resources to finance expansion. This implies there would be clear trade-offs.

As used in this chapter, the term 'intensify' refers to the adoption of cattle production systems that have higher output per hectare. This can be achieved through the use of various pasture and herd management practices, increased use of purchased inputs and/or improved breeding stock. We focus exclusively on small-scale farmers, because of their large numbers and their importance in cattle management; an estimated 500,000 smallholders live in the forest margins of the Brazilian Amazon and, by 1995, over 40% of the total cattle herd in the state of Acre was held on ranches smaller than 100 ha (IBGE, 1997).

The next section gives background on the Amazon, its development and the policies that have influenced development over the past few decades. Section 3 provides a general overview of smallholder land-use patterns in the western Brazilian Amazon and describes the production systems that generate those patterns. Section 4 describes selected livestock production systems in the western Brazilian Amazon and the capital and labour requirements associated with establishing and managing these systems. It also looks at what these summary statistics can tell us about technology adoption and the links between intensification and deforestation. Section 5 presents a farm-level bioeconomic linear programming (LP) model, which allows us to directly assess the adoptability and impact (if adopted) of more intensive pasture and cattle production systems. Section 6 presents and compares the results of model simulations used to make these assessments, paying special attention to land use (including deforestation), herd dynamics and household income. Conclusions and policy implications appear in section 7.

2. Tapping the Resources of the Amazon

The Amazon basin occupies 7.86 million km^2 in nine countries, covers about 44% of the South American continent and houses the largest tracts of the world's remaining tropical moist rain forests (Valente, 1968). More than 60% of the Amazon forest is located in northern Brazil. This forest covers over 52% of Brazil's entire national territory (IBGE, 1997), an area larger than Western Europe (INPE, 1999).

Since the early 1960s, the Federal Government of Brazil has seen the Amazon region as a depository of huge amounts of natural resources (forests, agricultural land, minerals, etc.) to be used to fuel economic growth. To exploit those resources and integrate the region into the national economy required a substantial workforce. However, the region's low population density (about 0.9 km^{-2} in 1970) made labour scarce. The government also viewed the virtual absence of Brazilian citizens as a threat to national security, particularly given the flourishing illicit drug trade in neighbouring countries (Forum Sobre a Amazônia, 1968; Government of Brazil, 1969, 1981; SUDAM, 1976; Smith *et al.*, 1995; de Santana *et al.*, 1997; IBGE, 1997; Homma, 1998).

Tapping the Amazon's resources and developing the region proved difficult. Huge distances and poor or non-existent infrastructure separated the area from the major markets. This made the region's inputs expensive and its products less valuable. The huge diversity of the Amazon's mosaic of ecosystems saddled planners with the unexpected need for expensive niche-specific projects and programmes. Indigenous people became increasingly vocal about their claims to large tracts of land and the associated resources. Simultaneously, the international community began to pressure the Brazilian government regarding its planned uses of the Amazon, based on its own concerns about greenhouse-gas emissions and biodiversity conservation.

Despite large gaps in knowledge, the Federal Government decided to go ahead with its homogeneous set of policies aimed at developing the Amazon region. To this end, it initiated 'Operation Amazon' in 1966 and set out a broad geopolitical and economic plan for the region (Government of Brazil, 1969; Mahar, 1979; de Santana *et al.*, 1997). To supply the legal framework, financial resources, transportation networks and electric power needed to establish migrants and industry in the Amazon, the government created a plethora of regional development agencies and policy instruments. These included the Amazon Development Agency (SUDAM), the Amazonian Duty-Free Authority (SUFRAMA) and the Amazonian Regional Bank (BASA). Often this support took the form of subsidized credit to agriculture (particularly extensive beef-cattle ranching) and mining projects (Forum Sobre a Amazônia, 1968; Government of Brazil, 1969, 1981; SUDAM, 1976; Smith *et al.*, 1995; IBGE, 1997; de Santana *et al.*, 1997).

In the early 1970s, world economic and oil crises led to a severe economic recession in Brazil. This, combined with agricultural modernization and consequent changes in farm structure, generated large increases in unemployment and landlessness in southern Brazil, as well as social conflicts. The Federal Government saw the opportunity to solve two problems at once. By moving unemployed and landless people to the Amazon and establishing them in settlement projects, it could both reduce social pressures in the south and increase the supply of labour for development activities in the north (SUDAM, 1976; Government of Brazil, 1981; Bunker, 1985). In the efforts to encourage landless people to migrate and colonize, millions of hectares of forested land were turned over to small- and large-scale farmers, despite limited knowledge about whether these areas could support viable agriculture (Valentim, 1989; Wolstein *et al.*, 1998). Incentives to migrate were successful; in the western Brazilian Amazon population grew substantially. The neighbouring State of Acre's 1950 population of about 100,000 jumped to nearly 500,000 by 1996. Rondônia's population went from under 100,000 to over 1.2 million during the same period.

The process of converting forest to agriculture in the western Amazon states of Acre and Rondônia has now been under way for over two decades, and has had major direct and indirect impacts on growth, poverty alleviation and environmental sustainability – a 'critical triangle' of development objectives (Walker and Homma, 1996; Vosti *et al.*, 2001).

Economic growth has been substantial. Rondônia had become the third largest coffee-producing state in Brazil by 1997 and now has some 4 million head of cattle (IBGE, 1997; Soares, 1997). In neighbouring Acre, the area dedicated to agriculture increased from virtually zero in1975 to about 10% of the state's total area by 1999. Acre's cattle herd grew from practically nothing in 1975 to nearly 800,000 head in 1998 (IBGE, 1997). Pasture is the dominant use of cleared land in both states, occupying 1.4 million ha in Acre and about 5.4 million ha in Rondônia (IBGE, 1997).

Progress on poverty alleviation has also been impressive. Between 1970 and 1996, the United Nations Development Programme (UNDP) human development index in Acre rose from 0.37 to 0.75. Over the same period, life expectancy at birth climbed from about 53 years to over 67 and adult literacy shot up from about 47% to over 70% (UNDP, 1998).

The environmental record has been less encouraging. Roughly a quarter of Rondônia's forests have been converted to agriculture over the past 20 years, and about 70% of this is area currently dedicated to low-productivity pastures. Acre has suffered less deforestation (averaging about 0.5% per year over the 1989–1997 period, compared with 1.5% in Rondônia). But declining earnings from traditional extractive activities in Acre may lead to increased forest clearing for agriculture, perhaps even by rubber tappers (Homma, 1998; INPE, 1999).

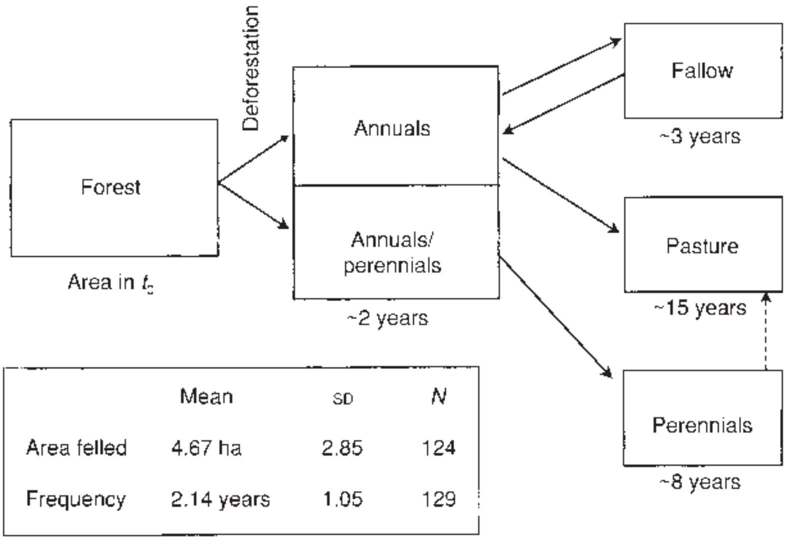
In summary, forest conversion and subsequent agricultural activities have improved the welfare of many rural families. Nevertheless, questions persist about whether these gains will prove sustainable and replicable. The future role of cattle production in the region is also in doubt and many people are looking for alternative ways to increase growth and reduce poverty that involve less forest conversion (Serrão and Homma, 1993).

The search for alternatives will not be easy. In many ways the 'deck is stacked' in favour of extensive agricultural activities, particularly cattle production. As farmers weigh the relative returns to scarce factors in this generally land-abundant and labour-scarce region, characterized by large distances to major markets and imperfect credit markets, it is not surprising that they have turned to livestock (Vosti *et al.*, 2000). Cattle production systems dominate the landscape, and it is difficult to imagine any production system displacing them. One logical point of departure in the search for alternatives, then, is to ask whether there is any way to modify the current extensive cattle production systems (which consume large amounts of forest) in order to make them both more productive and less destructive to forests. The following sections turn to precisely that question.

3. Smallholder Land Uses and Land-use Systems

According to survey data from smallholders in the western Brazilian Amazon, forest continued to cover about 60% of the land on the average farm in 1994 (Witcover and Vosti, 1996). Pasture dominated the use of cleared land (taking up about 20% of total farm area), followed by fallow (8%), annual crops (6%), perennial tree crops (3%) and intercropped annual/perennial areas (1%). Moreover, the average proportion of cleared land dedicated to pasture and cattle production activities increased by roughly 5% of farm area in the space of 2 years, mirroring state-wide trends (Vosti *et al*., 2001).

The predominant land-use trajectory (Fig. 7.1) begins with the clearing of the forest and ends in the establishment of pasture (Leña, 1991; Dale *et al*., 1993; Browder, 1994; Jones *et al*., 1995; Fujisaka *et al*., 1996; Scatena *et al*., 1996; Vosti and Witcover, 1996; Walker and Homma, 1996; Vosti *et al*., 2001). Newly deforested land (on average, about 4.7 ha every other year) generally goes into annual crop production for about 2 years. After that, three possibilities exist. Farmers can put the land into a fallow rotation lasting about 3 years, after which it can be returned (usually only once) to annual crop production. Or farmers may put the land into perennial tree crops, which, depending on the type of tree crop and its management, can last up to a decade before replanting (some external inputs are required). Or farmers can dedicate the land to pasture, where, depending on herd and pasture management



	Mean	SD	*N*
Area felled	4.67 ha	2.85	124
Frequency	2.14 years	1.05	129

Fig. 7.1. Observed land-use trajectories by small-scale farmers. Number of years noted below each land-use box indicates time continuously in a given land use, and not the time elapsed since t_0 (the year in which deforestation on a given plot of land occurs).

practices, it can remain productive for 15 years or more.[3] This chapter examines how attempts to intensify this 'final' activity of the most common land-use trajectory affect deforestation and farmer livelihoods.

4. Traditional and Intensified Cattle Production Systems

Large farms, which have to a certain degree intensified their production systems, dominate the agricultural landscape in the western Brazilian Amazon. Farms larger than 200 ha accounted for roughly 70% of all planted pastures in Acre in 1995 (IBGE, 1997). Nevertheless, smallholders (less than 200 ha) managed 49% of the state's natural pastures, all low quality and degraded (IBGE, 1998).

Smallholder production systems in the western Amazon tend to have low stocking and calving rates and to generate returns to labour similar to the prevailing rural wage rate (Vosti *et al.*, 2000). In spite of their modest profitability, several features make these systems attractive to many farmers. They are easy to manage and demand little technical expertise. They are inexpensive to establish and maintain, and require few purchased inputs. Cattle can assist farmers in slowing spontaneous forest regeneration, which can be rapid, even on soils depleted by annual crop production. Finally, labour and/or credit constraints limit farmers' ability to expand into more profitable alternatives, such as small-scale coffee production. Often they are left with significant amounts of cleared land that they cannot use for anything but cattle, given the amount of labour and capital available.

Some smallholders are, nevertheless, intensifying their cattle production systems. The remainder of this section defines 'traditional' and 'more intensive' production systems and then examines the capital and labour requirements of establishing and managing each of them.

Tables 7.1 and 7.2 present the technical coefficients for three types of pasture production systems and two types of dairy systems in Acre. Each column in the tables represents a different technological 'package'. The rows show resource requirements and expected production, over a 20-year period. We derived the technical coefficients for all the production systems from focus-group meetings with farmers, agricultural extension agents and researchers, and from field research (EMATER-Acre and Embrapa, 1980; Carpentier *et al.*, 2001).

The first technological package described in Table 7.1 is the traditional pasture system (labelled P1). Farmers with this system use a traditional grass called Brizantão (*Brachiaria brizantha*). They manage the pasture poorly and the pastures display high levels of weed invasion. The more intensive grass-based system (labelled P2) also uses Brizantão, but farmers rotate grazing on and weed these pastures and consequently have fewer weed problems. The third pasture system (labelled P3) is the most intensive and incorporates the use of tropical kudzu, a legume, in addition to Brizantão (see

Chapter 12 by Yanggen and Reardon in this volume). In addition, the pasture is well managed. Ranchers rotate grazing on their pastures adequately and weed invasions are not prevalent.

Table 7.1 shows that P2 and P3 technologies significantly increase the lifespan and carrying capacity of the pasture system, compared with the traditional system. Two factors are chiefly responsible for this. First, P2 and P3 initially use more labour for weeding, green chop and pasture maintenance. Secondly, and perhaps more importantly, they use nearly twice as much

Table 7.1. Small-scale pasture production systems for Acre, by level of technology.

	Grass		Grass/legume
Technical coefficients	P1	P2	P3
1. Inputs			
Seeds (kg ha^{-1})			
Brizantão	15	15	15
Kudzu			1
Labour (man-days ha^{-1} year^{-1})			
Seeding (year 1)	3	3	3
Weeding (year 1)	2	3	3
Weeding and P3 green chop (years 2–4)	2	3	3
Weeding and P3 green chop (years 5–11)	2	3	1.5
Fencing			
Length (km of fence ha^{-1} of pasture)	0.063	0.106	0.106
Oxen time (man-days km^{-1} of fence)	4	4	4
Own chain-saw (man-days km^{-1} of fence)	4.5	1	1
Labour (man-days km^{-1} of fence)	59	56	56
Total costs (R$ km^{-1} of fence)*	302	347	347
2. Production			
Carrying capacity (animal units ha^{-1}, rainy season)			
Year 2–3	1	1	1.5
Year 4	1	1	1.5
Year 5	0.88	0.99	1.5
Year 6	0.79	0.97	1.5
Year 8	0.49	0.9	1.5
Year 9	0.39	0.85	1.5
Year 10	0.29	0.8	1.5
Year 11	0.3	0.85	1.48
Year 15	0	0.65	1.4
Year 20	0	0.15	0.9

*All values are in 1996 Brazilian reais, labelled R$; in 1996, one R$ was roughly equivalent to one US$.

fencing to segment pastures. The same two aspects that contribute to higher yields, however, can be formidable obstacles to adoption. Farmers may lack the labour and expertise required for managing legume-based pastures, as well as the capital to make substantial outlays for fencing.

Table 7.2 presents technical production coefficients for two types of dairy production systems – D1 (traditional, low-input) and D2 (more intensive). The pasture and the dairy packages are 'coupled', i.e. more intensive cattle production can only occur alongside more intensive pasture production, and vice versa. The first block of rows in Table 7.2 shows the herd input requirements for feed supplements, animal health and labour. The second

Table 7.2. Small-scale dairy production systems in Acre, by level of technology.

Technical coefficients	D1	D2
1. Herd inputs		
Feed supplements		
Elephant grass, forage (kg animal^{-1})	0	20
Salt (kg animal^{-1} year^{-1})	110	0
Mineral salt (kg animal^{-1} year^{-1})	0	18.25
Animal health		
Aftosa (foot and mouth disease) (vaccinations animal^{-1} year^{-1})	2	2
Brucellosis (vaccinations female calf^{-1} year^{-1})	0	1
Rabies (vaccinations animal^{-1} year^{-1})	0	1
Carrapaciticida (ml of butox animal^{-1} year^{-1})	5	10
Worm control (ml animal^{-1} year^{-1})	10	25
Antibiotics		
Mata bicheira (cc animal^{-1} year^{-1})	0	0.03
Terramicina (ml year^{-1} to half the herd)	0.06	0.13
Labour for herd management		
Milking (man-days lactating cow^{-1} month^{-1})	0.9	1.5
Other activities (man-days animal unit^{-1} month^{-1})	0.3	0.6
2. Herd dynamics		
Calving rate (% cows giving birth year^{-1})	50	67
Mortality rate (death rates, by age, %)		
< 1 year	10	6
< 2 years	5	3
> 2 years	3	2
Culling/discard rate (% animals discarded year^{-1})		
Cows	0	10
Bulls	6	12
3. Milk production		
Milk production dry season (litres day^{-1})	2.5	4.5
Milk production wet season (litres day^{-1})	3	6
Lactation period (days year^{-1})	180	240

block of rows presents herd demographics. The final block of rows presents milk production coefficients.

As in the case of pasture systems, different production systems involve different levels of investment and changes in management strategies. The traditional dairy system uses low-productivity cattle. Ranchers need little expertise to manage the system, which also makes minimal use of purchased inputs. In contrast, the more intensive dairy system involves an improved breed of cattle, substantial use of purchased inputs and improved animal husbandry techniques.[4] Not only must the rancher purchase animals of higher quality, he or she must also manage the herd more intensively to realize that genetic potential.

The D2 dairy system requires substantially more purchased inputs than the D1 system. Ranchers provide the cattle with mineral salt and elephant grass (green chop) in the dry season, rather than simple salt. The types, number and dosages of vaccinations also increase.

Herd management (culling and discard rates) changes radically in the D2 system. Ranchers using the D1 system do not necessarily discard their cows, although older cows are generally sold, depending on liquidity needs. In contrast, with D2 technology 10% of cows (the oldest and least productive) must be discarded each year to achieve productivity goals.

These changes in the herd genetic composition and management techniques lead to large differences in milk production. Moving from D1 to D2 technology roughly doubles daily milk offtake and increases lactation periods by about one-third.[5]

Tables 7.3, 7.4 and 7.5 summarize the capital and labour requirements for the establishment and maintenance phases of P1 and P2 pasture systems, coupled dairy–pasture systems (D1–P1, D2–P2 and D2–P3) and coupled beef–pasture systems (B1–P1, B2–P2 and B2–P3), respectively.

During the pasture establishment period (Table 7.3), which lasts for about 1 year for all the technologies, switching from P1 to P2 technologies requires substantial (but not proportional) increases in capital and labour. Capital inputs increase by about 60% and labour requirements roughly double. During the maintenance phase, however, no capital is required and, depending on which of the two more intensive technologies the rancher adopts (P2 or P3), labour use can increase or decrease. P2 grass-based pastures require more labour for weeding than do P1 pastures, but P3 legume-based pastures require less. Finally, the capital/labour ratios show that P2 and P3 pastures (but especially P2) are more labour-intensive than traditional pasture technologies.

Adding information on pasture costs to the establishment and operational costs associated with different intensities of dairy production yields Table 7.4.[6] Several results emerge. To establish a D2–P3 system requires about 2.5 times more capital than to establish a traditional dairy/pasture system (D1–P1), primarily due to the costs of acquiring a more productive herd. In addition, the labour required for establishing more intensive systems more than doubles, primarily due to more fence building. Thirdly, due to increased milking

Table 7.3. Capital and labour requirements for establishment and maintenance of pastures, by technology, per hectare.

	Pasture traditional P1	Pasture grass-based P2	Pasture legume/ grass-based P3
Establishment period (1 year)			
Capital requirements ($R\$\ ha^{-1}\ year^{-1}$)	152	241	252
Labour requirements (man-days $ha^{-1}\ year^{-1}$)	6.3	11.4	11.4
Labour requirements ($R\$\ ha^{-1}\ year^{-1}$)	37.2	64.2	64.2
Maintenance period*	10 years	14 years	19 years
Capital ($R\$\ ha^{-1}\ year^{-1}$)	0	0	0
Labour (man-days $ha^{-1}\ year^{-1}$)	1.1	1.3	0.6
Labour ($R\$\ ha^{-1}\ year^{-1}$)	5	8	3.5
Key ratios			
Establishment period			
Capital/labour ratio (R$/R$)	4.1	3.8	3.9
Maintenance period			
Capital/labour ratio (R$/R$)	0	0	0

*Maintenance period is defined as the number of years during which inputs are used to manage pastures. The useful life of pastures can extend a few years beyond the maintenance period.

and herd management costs, it costs nearly three times as much in labour to operate a D2–P3 system than to operate a D1–P1 system. Finally, in the operational phase, the capital and labour costs of the most intensive system (D2–P3) are about seven and two times greater, respectively, than in the traditional system. (These are all dairy-cattle costs. The pastures require no capital during the operational phase.)

The much higher capital and labour requirements of the more intensive systems can limit their adoption, especially in areas with poorly functioning financial and labour markets. But, as we show below, the more intensive systems are much more profitable. So, once established, we expect them to generate sufficient cash to cover all labour and capital costs.

The more intensive D2–P2 systems are more labour-intensive than the D1–P1 systems in the establishment phase (i.e. they have lower capital-to-labour (K/L) ratios), because the labour required to weed the pastures increases substantially. In contrast, the legume-based D2–P3 system is more capital-intensive than the D1–P1 system, this time due to substantial increases in purchased inputs for herd management. In the operational phase, the K/L ratio rises (i.e. the systems become more capital-intensive) as we move from the traditional to more intensive systems.

Table 7.4. Capital and labour requirements for establishment and maintenance of dairy/pasture production systems, on a per-hectare basis.*

	Traditional dairy/pasture system D1–P1	Improved dairy/grass-based pasture system D2–P2	Improved dairy/legume-based pasture system D2–P3
Establishment period (1 year)			
Capital requirements (R$ ha^{-1})	252	479	692
Labour requirements (man-days ha^{-1})	7.6	15.9	19.6
Labour requirements (R$ ha^{-1})	43.2	84.7	102
Maintenance period	10 years	14 years	19 years
Capital (R$ ha^{-1} $year^{-1}$)	1.2	4.6	8.5
Labour (man-days ha^{-1} $year^{-1}$)	3.6	8.2	10
Labour (R$ ha^{-1} yrea)$^{-1}$	21	44.5	48.2
Key ratios			
Establishment period			
Capital/labour ratio (R$/R$)	5.8	5.7	6.8
Maintenance period			
Capital/labour ratio (R$/R$)	0.06	0.10	0.18

*Combined dairy/pasture system requirements are averaged over 20 years, for all systems, to capture declining carrying capacity and the 'zero input' status of P1 and P2 grass systems, which are untouched after years 11 and 15, respectively. P1 pastures become unproductive in year 15, but we continue to use this now idle land to weigh calculations of average input requirements and production.

Finally, Table 7.5 combines information on pasture costs with the establishment and operational costs associated with different levels of intensity of beef-cattle production. Moving from a traditional beef system (B1–P1) to more intensive systems increases the absolute outlays for capital and labour during both the establishment and operational phases of production. Labour costs during the operational phase more than double with a shift from B1–P1 to B2–P2, but the rise is less steep with the adoption of B2–P3, since it has lower pasture management costs than B2–P2. The K/L ratio during the establishment period for beef/pasture systems is basically unchanged by the move from B1–P1 to B2–P2, but increases for the B2–P3 system. Finally, the K/L ratio during the maintenance period increases with the adoption of more intensive systems, due primarily to increased costs of maintaining herd health.

What can these summary tables tell us about technology adoption and the possible links between the intensification of cattle production systems and deforestation? If we keep in mind that small-scale farmers at the forest margins generally operate in labour- and capital-constrained contexts, and if we focus only on how they are likely to allocate their initial available resources and how that might affect deforestation, we can deduce the following.

Table 7.5. Capital and labour requirements for establishment and maintenance of beef/pasture production systems, on a per-hectare basis.*

	Traditional pasture/beef system B1–P1	Improved beef/ grass-based pasture system B2–P2	Improved beef/ legume-based pasture system B2–P3
Establishment period (1 year)			
Capital requirements (R$ ha^{-1})	200	356	464
Labour requirements (man-days ha^{-1})	6.8	13	14.3
Labour requirements (R$ ha^{-1})	39.7	71.5	77.7
Maintenance period	10 years	14 years	19 years
Capital (R$ ha^{-1} $year^{-1}$)	0.6	2.4	4.4
Labour (man-days ha^{-1} $year^{-1}$)	2.8	5.3	4.7
Labour (R$ ha^{-1} $year^{-1}$)	17.5	31.3	23.9
Key ratios			
Establishment period			
Capital/labour ratio (R$/R$)	5.0	5.0	6.0
Maintenance period			
Capital/labour ratio (R$/R$)	0.03	0.08	0.18

*Combined beef/pasture system requirements are averaged over 20 years, for all systems, to capture declining carrying capacity and the 'zero input' status of P1 and P2 grass systems, which are untouched after years 11 and 15, respectively. P1 pastures become unproductive in year 15.

First, traditional beef production systems have the lowest absolute input requirements. In addition, more intensive dairy systems have consistently higher absolute capital and labour requirements than more intensive beef systems – in some cases, substantially higher. Therefore, based on absolute input requirements alone, farmers in severely constrained capital and labour situations should find beef systems in general, and traditional beef systems in particular, most attractive.

Secondly, traditional and more intensive systems have quite similar establishment costs, but the role of capital in maintaining both dairy and beef systems increases markedly as these systems intensify. Based on K/L ratios, the capital constraints to establishing more intensive systems appear relatively similar across all systems, but the more intensive systems impose relatively higher capital constraints faced during the operational phases of production.

Based on absolute input requirements alone, farms adopting dairy production systems of any type should deforest less than those adopting roughly comparable beef production systems. With any given amount of labour and capital the rancher has available, he or she will be able to establish a smaller area with the dairy system than with a beef system that has a comparable level of intensity. Following the same logic, intensifying any livestock production systems that involves grass-based pastures should reduce deforestation, since intensive systems require more capital and labour. However, the most intensive, legume-based pasture management system actually releases labour, which could be used for deforestation.

Dairy systems are slightly more capital-intensive to establish than beef systems with a comparable level of intensity (i.e. they have a higher K/L ratio). However, since the establishment period lasts only a year or so for all systems, the K/L ratio during the operational phase will have a longer (and perhaps greater) influence on deforestation. The latter increases steadily as dairy and beef systems become more intensive, suggesting that, if forest clearing were a relatively capital-intensive activity, intensification of cattle production activities would reduce deforestation by drawing capital away from forest-felling activities.

Nevertheless, this analysis of the links between technology and deforestation, based solely on Tables 7.3 to 7.5, misses several key aspects. First, it fails to address the profitability of the activities, and it is via profits that key farm-level constraints to system adoption and expansion will be overcome. Secondly, it does not specify what the smallholders' objectives are. Thirdly, and perhaps most importantly, the tables present particular activities in isolation of one another and independent of other on- and off-farm activities. The interdependencies among these competing activities may be much more important in determining intensification/deforestation links than the requirements of any specific activity, especially in capital- and labour-constrained environments. To include these elements, we need an approach that looks at the whole farm. The following section takes such an approach.

5. A Farm-level Model

Farmers allocate land, labour and capital based on the expected returns to alternative on- and off-farm activities. Some activities, such as annual cropping, can generate short-term returns. Others, like cattle production, bring returns over the medium term. Still others, including producing timber-trees, offer returns only over the long term. Since poor smallholders prefer short-term returns to long-term returns, timing matters a great deal.

When deciding between activities, farmers also face economic and biophysical constraints. For example, households do not have an unlimited supply of labour to allocate to production and some cropping patterns are simply not feasible on poor soils. The fact that smallholders are often constrained in their access to factors of production implies that different activities compete with each other for household resources. Thus, even if a particular activity like cattle production or agroforestry looks quite promising when examined in isolation, it may turn out to be less profitable than alternative activities. To deal with the timing of returns, the degrees to which biophysical or other constraints limit choices and the extent of on-farm competition among activities for scarce resources requires a long-term, whole-farm view and analytical tools that are based on such a view.

We developed a farm-level bioeconomic LP model to explicitly account for the biophysical and economic factors that determine farmers' land-use decisions and choices of production techniques.[7] The model assumes that farmers maximize the discounted value of their families' consumption streams (directly related to, and hence below referred to as profit stream) over a 25-year time horizon by producing combinations of products for home consumption and sale, subject to an array of constraints. These constraints relate to the technologies available to produce agricultural and forest products, the impact of agricultural activities on soil productivity and the financial benefits associated with different activities, including the potential to sell household labour off-farm and to hire labour for agricultural purposes. Besides producing agricultural products, farmers in our model also have the option of extracting Brazil nuts, an activity that generates a low but constant per-hectare return. The model also includes biophysical constraints, e.g. how soil fertility problems restrict agricultural productivity and soil recovery, and to what extent external inputs can correct these problems.

The model begins from a prespecified set of initial conditions. These include the initial land use on the farm (depicted on the vertical axes of Figures 7.2 and 7.3 at 'year zero'), as well as a number of farm- and household-specific constraints (for example, family size and distance to market) that can influence the allocation of land, labour and cash to alternative land uses.[8] The model also takes into account certain market imperfections, e.g. quotas constrain milk sales and farmers can only acquire 15 man-days of hired labour in any given month. Finally, the model explicitly includes some forestry policies, but excludes others. Small-scale farmers are not allowed to harvest timber products from their forested land. However, the rule that forbids farmers from clearing more than half of their farm for agricultural purposes is not enforced in the model simulations presented here.[9]

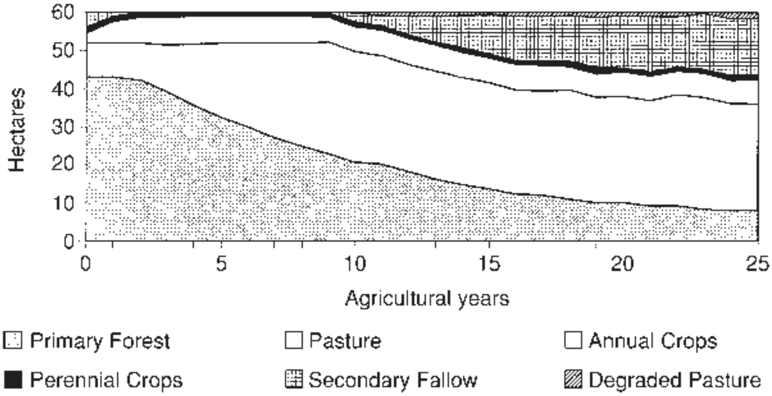


Fig. 7.2. Land uses under traditional-only cattle/pasture production technologies.

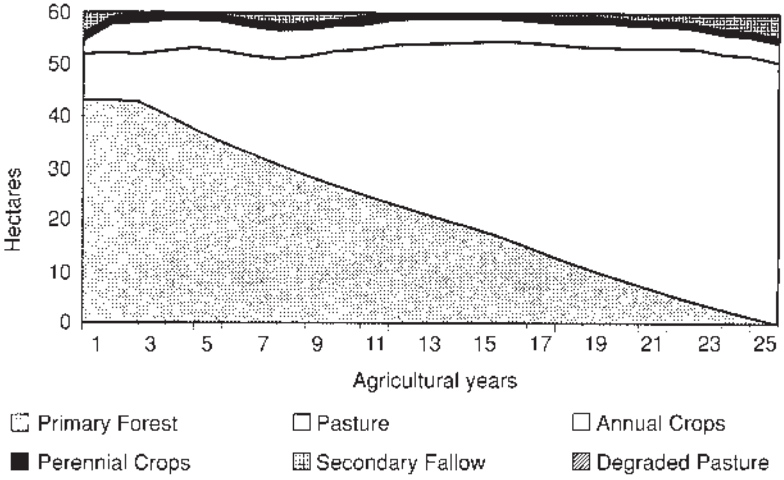


Fig. 7.3. Land uses under the 'free-choice' cattle/pasture production technologies.

6. Results of Model Simulations

We present two sets of simulations to assess how introducing the more intensive pasture and cattle (beef and dairy) production technologies described above may affect deforestation and farm income, as well as whether farmers would find the more intensive systems more economically attractive. First, we constrain our representative small-scale farmer to use only traditional (B1–P1 and/or D1–P1) traditional production technologies. Then we allow the farmer to select whichever pasture and cattle technologies maximize profits. In both simulations, the farmer can choose mixed beef/dairy herds, dairy only or produce no cattle at all if other activities provide higher profits than cattle production.

6.1. Scenario 1: low-intensity technology only

When we restrict our representative small-scale farmer to adopting B1–P1 and/or D1–P1 cattle and pasture production systems, he or she chooses both. Figure 7.2 presents the resulting land uses (including deforestation) over the simulation's 25-year time horizon.[10] Deforestation begins slowly, accelerates from about year 3 to year 15, and then slows substantially (but does not stop). Pasture area expands dramatically between year 3 and about year 10, and remains constant thereafter at roughly 50% of farm area. Area dedicated to annual and perennial crops remains roughly constant over the entire period. Secondary fallow area increases substantially, beginning in about year 8. Finally, beginning in about year 10, small amounts of land are dedicated to rehabilitating degraded (though not necessarily completely unproductive) pastures.

Herd growth (not shown here) under the traditional technology simulation is moderate. Total carrying capacity of pastures reaches a maximum of about 23 animal units in year 9. Milk cows constitute one half of the herd in year 9 and calves and beef cattle account for the other half. The latter become important beginning in year 5 and their number stabilizes after about year 9.

6.2. Scenario 2: free choice between traditional and more intensive technologies

When we allow our representative farmer to choose from a combination of pasture and cattle production technology packages, the model predicts the adoption of D2–P3 and B2–P3 technologies. Figure 7.3 shows how we expect land use to evolve. The amount of forest clearly declines over time, finally disappearing in about year 25. Pasture eventually occupies about 85% of the farm. Annual crops occupy about 8% of the farm throughout the 25-year time horizon. Perennial crops (in this case, manioc, which has a production cycle spanning more than 1 year) consistently take up about 1 ha of land. Secondary fallow fluctuates, becoming significant as forests disappear.[11]

Under the ‘free-choice’ scenario, herd growth (not shown here) is rapid and sustained. By about year 15, pastures can support roughly twice the number of animal units as the ‘traditional technology only’ farm. As in the traditional-technology scenario, dairy production using D2–P3 technology begins early on and continues to play an important role throughout. But the scale of milk production is more than double that of the traditional-technology farm. Beef (produced using B2 technology) emerges more slowly than in the traditional-technology case, but still eventually comprises about 25% of the total herd.

Of critical interest to small-scale farmers is the profit stream they can hope to earn in each of these scenarios. The second scenario, which permits farmers to adopt the more intensive technologies, consistently provides higher profit streams than the traditional-technology scenario. The net present values (NPV) of the profit streams for the traditional and ‘free-choice’ scenarios are R$19,813 and R$50,635, respectively.[12] Savings during the first few years allow for subsequent investments, which boost production (and profits) in later years. To expand P3 pasture areas and purchase high-quality D2 and B2 cattle require large investments (negative savings) in years 5, 9 and 11.

7. Conclusions and Policy Implications

The chapter has addressed three central questions in the context of small-scale agriculture at the forest margins in the western Brazilian Amazon:

1. Do more intensive pasture and cattle production systems exist and, if so, what are their labour and capital requirements?

2. If they exist, will they be adopted, and why/why not?
3. If adopted, what will the impacts be on deforestation and on farm income?

Field research confirms that some types of more intensive, sustainable pasture and cattle production systems exist and smallholders are adopting them. More intensive systems have pastures with higher carrying capacity, which produce more animal products and which can last longer than traditional systems, but require more capital and labour to establish and manage. The K/L ratios during the establishment phases of production are higher for dairy than for roughly comparable beef production systems. The same applies to the operational phases of comparable production systems, except in the case of the most intensive beef and dairy systems, which have similar K/L ratios.

Secondly, many more smallholders are likely to adopt the more intensive pasture and cattle production systems in the future, since the financial returns from the more intensive systems are much higher than those of traditional systems.

Thirdly, more intensive systems will probably increase, rather than decrease, the pressure on the forests that remain on farmers' land. Greater profitability will create a demand for larger milking and beef cattle herds and pasture to support them. The only major constraint on forest conversion at the farm level will be seasonal labour shortages. This, however, only becomes clear once one takes a 'whole-farm' view, which allows comparison of the returns to scarce resources across many possible activities and over time.

There are several caveats, though. Many smallholders in the region may not have enough capital and labour to establish and manage more intensive cattle–pasture systems and so poorly performing capital and labour markets could limit adoption. Credit can help promote adoption, even without high or long-term credit subsidies, since these more intensive systems generally become profitable within a few years of establishment.

Secondly, farmers will have to change their production practices to adopt and effectively use more intensive systems and there is no guarantee that they will have the information and ability they need to make those changes. If they do not establish and manage their intensive systems well, they will get lower returns and cause greater soil and pasture degradation.

Thirdly, in the analysis presented here, it is assumed that the entire technology package was adopted. If only certain components of the packages were adopted, profits and/or environmental sustainability could be undermined.

Fourthly, while the clear trade-off between the greater profitability of the more intensive systems and the higher deforestation associated with them should concern policy-makers, it also provides an entry point for policy action. Policy-makers may now have something to offer to farmers in exchange for reduced forest clearing. More intensive livestock systems will require additional research and extension services for smallholders to properly establish and manage them. Policy-makers can provide smallholders with both. The private sector is actively developing some improved technologies and promoting them to large-scale ranchers, but may not pay much attention to smallholders. Policies that guarantee access to processing facilities for fluid milk may also be needed. Here too, policy-makers can help. In exchange for research, extension services and improved infrastructure, policy-makers could ask farmers to slow deforestation (perhaps by adhering to the 50% rule). Farmers would probably have a financial incentive to agree to such a plan, but problems of monitoring and implementation clearly remain.

Notes

1 This chapter benefited greatly from technical field data provided by Merle Faminow, Támara Gomes, Claudenor Sá and Samuel Oliveira, comments by the editors, an anonymous referee, participants in the CIFOR workshop on agricultural intensification–deforestation links, colleagues in the Alternatives to Slash-and-Burn Agriculture Programme (ASB) and participants at seminars at the International Food Policy Research Institute, the H.A. Wallace Institute, the Empresa Brasileira de Pesquisa Agropecuária and the University of Maryland. Financial support was provided by the Inter-American Development Bank and the World Bank. We dedicate this chapter to the memory of Erennio Giacomazzi, who provided office space and much moral support.

2 Technology adoption issues addressed in this chapter focus primarily on economic viability; for a more comprehensive set of adoption issues in the same socio-economic and agroclimatic setting, see Vosti *et al.* (2000).

3 Earlier reports suggested that cattle production systems and especially the pastures associated with them could not be sustained for more than a few years (Hecht, 1984). More recent evidence on traditional and emerging cattle production systems shows that both are much more sustainable than previously thought (Faminow and Vosti, 1998).

4 The input and output coefficients for traditional and more intensive dairy and beef production systems presented in this section are based on completely specialized production schemes. In reality, mixed herds are quite common among smallholders in the region. These systems are examined in the context of the LP model presented in the next section.

5 We conducted similar analyses of traditional and more intensive beef production systems. These systems are basically calf-purchasing and fattening operations. Space constraints preclude a detailed presentation of these systems here, but more intensive systems increase calf weights by 25%, increase slaughter weight slightly and greatly speed the fattening process. Combined beef–pasture systems are examined at the end of this section.

6 Recall that, by assumption, pasture and cattle production systems (dairy and beef) are ‘coupled’. P1 pasture can only support D1 dairy and B1 beef production and P2 pasture is not used in D1 or B1 systems. Field observations support this assumption.

7 For a complete description of the LP model, see Carpentier *et al.* (2001).

8 These initial conditions are based on field data collected in 1994. We used statistical techniques to cluster farm households from the Pedro Peixoto settlement project in Acre into several groups, based on certain characteristics that we felt were exogenous to the farmers' land-use decisions, such as soil type, distance to market and duration of settlement. Several clusters emerged, each of which can be thought to

represent a farm type. We used the average characteristics for the farm type with relatively good access to markets to obtain the initial conditions for our model. The predominant soil types in this cluster of farms had fertility problems and/or mild slope or rockiness partially restricted their agricultural productivity. The model simulations in this chapter take the characteristics of this typical farm as their point of departure.

9 This analysis ignores general equilibrium effects. That may not be justifiable for some products and/or technological changes. For example, to analyse non-timber forest products, which face notoriously thin and seasonal markets, one must take into account the fact that technologies that increase their supply may decrease output prices. In our case, however, which focuses on cattle production, it seems reasonable to ignore general equilibrium effects. Beef is traded internationally and regional supply still does not completely satisfy regional demand, so small-scale farmers can be characterized as price takers in a fairly competitive market (Faminow and Vosti, 1998). Farmers can also increase milk production without significantly depressing prices, since up to 80% of milk processing capacity is idle during at least some part of the year (J.F. Valentim, personal observations).

10 None of the simulations presented in this chapter reach steady-state land uses. Therefore, we cannot assess the potential for any collection of activities (or technologies) to sustain a small-scale farm family over the very long term.

11 Extending this simulation to 35 years shows that the area in secondary fallow continues to increase by approximately 0.20 ha every 2 years and plateaus at 5.5 ha in year 35.

12 We report all values in 1996 Brazilian reais. All the simulations use a constant set of 1993/94 input and product prices for the entire decision time horizon. We used a 9% discount rate to calculate NPV.

References

Brazil (1969) *Amazônia: Instrumentos Para o Desenvolvimento*. Ministério do Interior, Banco da Amazônia, Belem, Pará.

Brazil (1981) *III Plano Nacional de Desenvolvimento – 1980/85*. Presidencia da República, Secretaria de Planejamento, Brasília, DF.

Browder, J.O. (1994) Surviving in Rondônia: the dynamics of colonist farming strategies in Brazil's northwest frontier. *Studies in Comparative International Development* 29(3), 45–69.

Bunker, S.G. (1985) *Underdeveloping the Amazon: Extraction, Unequal Exchange, and the Failure of the Modern State*. University of Illinois Press, Urbana, Illinois.

Carpentier, C.L., Vosti, S.A. and Witcover, J. (2001) *FaleBEM: a Farm Level Bioeconomic Model for the Western Amazonian Forest Margin*. Discussion Paper, Environment and Production Technology Division, International Food Policy Research Institute, Washington, DC.

Dale, V.H., O'Neill, R.V., Pedlowski, M. and Southworth, F. (1993) Causes and effects of land-use change in central Rondônia, Brazil. *Photogrammetry Engineering and Remote Sensing* 59(6), 997–1005.

de Santana, A.C., de Alencar, M.I.R., Mattar, P.N., da Costa, R.M.Q., D'Ávila, J.L. and Souza, R.F. (1997) *Reestruturação Produtiva e Desenvolvimento na Amazônia: Condicionantes e Perspectivas*. BASA, Belém.

EMATER-Acre and Embrapa (1980) *Sistemas de Produção Para: Gado de Corte e Gado de Leite, Microregião Alto Purus.* Boletim No. 221, EMATER, Embrapa, Rio Branco, Acre, Brazil.

Faminow, M.D. and Vosti, S.A. (1998) Livestock–deforestation links: policy issues in the western Brazilian Amazon. In: Nell, A.J. (ed.) *Livestock and the Environment. International Conference, Wageningen, The Netherlands.* World Bank, Washington, DC, Food and Agriculture Organization, Rome.

Forum Sobre a Amazônia (1968) *Rio de Janeiro, RJ. Problemática da Amazônia.* CEB, Rio de Janeiro.

Fujisaka, S., Bell, W., Thomas, N., Hurtado, L. and Crawford, E. (1996) Slash-and-burn agriculture, conversion to pasture, and deforestation in two Brazilian Amazon colonies. *Agriculture, Ecosystems and Environment* 1015, 1–16.

Hecht, S.B. (1984) Cattle ranching in Amazonia: political and ecological considerations. In: Schmink, M. and Wood, C.H. (eds) *Frontier Expansion in Amazonia.* University of Florida Press, Gainesville, Florida.

Homma, A.K.O. (ed.) (1998) *Amazônia: Meio Ambiente e Desenvolvimento Agrícola.* Embrapa Produção de Informação, Brasilia, and Embrapa-CPATU, Belém.

IBGE (Instituto Nacional de Pesquisas Espacias) (1998) *Censo Agropecurária 1995–6*, No. 3. Acre, Rovaima e Amapá. IBGE, Rio de Janeiro, pp. 56–57.

IBGE (Instituto Brasileiro de Geografia e Estatística) (1997) *Anuário Estatistico do Brasil*, Vol.57. IBGE, Rio de Janeiro.

INPE (Instituto Nacional de Pesquisas Espaciais) (1999) Available at http://www.inpe.br/Informacões_Eventos/amz/amz.html. PRODES folder.

Jones, D.W., Dale, V.H., Beauchamp, J.J., Pedlowski, M.A. and O'Neill, R.V. (1995) Farming in Rondônia. *Resource and Energy Economics* 17, 155–188.

Leña, P. (1991) Ritmos e estratêgias de acumulação camponesa em ãreas de colonização: um exemplo em Rondônia. *Boletim Museu Paraense Emélio Goeldi, Seria Antropologia* 7(1), 37–70.

Mahar, D. (1979) *Frontier Policy in Brazil: a Study of the Amazonia.* Praeger, New York.

Scatena, F.N., Walker, R.T., Homma, A.K.O., de Conto, A.J., Palheta, Ferreira, C.A., de Amorim Carvalho, R., da Rocha, A.C.P.N., dos Moreira Santos, A.I. and de Oliveira, P.M. (1996) Cropping and fallowing sequences of small farms in the 'terra firme' landscape of the Brazilian Amazon: a case study from Santarem, Pará. *Ecological Economics* 18, 29–40.

Serrão, E.A.S. and Homma, A.K.O. (1993) Country profiles: Brazil. In: *Sustainable Agriculture and the Environment in the Humid Tropics.* National Research Council, National Academy Press, Washington, DC, pp. 265–351.

Smith, N.J.H., Serrão, E.A.S., Alvim, P.T. and Falesi, I.C. (1995) *Amazonia: Resiliency and Dynamism of the People.* United Nations University, New York.

Soares, O. (1997) *Rondônia Produz.* Senado Federal PTB, Brasília, DF.

SUDAM (Superintendência de Desenvolvimento da Amazônia) (1976) *II Plano de Desenvolvimento da Amazônia: Detalhamento do II Plano Nacional de Desenvolvimento (1975–79).* SUDAM, Belém, Pará.

United Nations Development Programme (UNDP) (1998) *Human Development Report.* United Nations Publications, New York.

Valente, M.G. (1968) A Amazônia brasileira e as outras amazônias. In: *Forúm Sôbre a Amazônia, 2, Rio de Janeiro, RJ. Problemática da Amazônia: Conferências.* CEB, Rio de Janeiro, pp. 277–295.

Valentim, J.F. (1989) *Impacto Ambiental da Pecuária no Acre*. Folio 2203, Documento base do Curso de Avaliação do Impacto Ambiental da Pecuária no Acre, 4 a 8 de dezembre 1989. EMBRAPA–UEPAE, Rio Branco.

Veja (1999) 7 April, pp. 108–115.

Vosti, S.A. and Witcover, J. (1996) Slash-and-burn agriculture – household perspectives. *Agriculture, Ecosystems and Environment* 58, 23–38.

Vosti, S.A., Witcover, J., Carpentier, C.L., Magalhães de Oliveira, S.J., dos Santos, J.C., with do Amaral, E., de Araújo Gomes, T.C., Borges de Araújo, H.J., Braz, E.M., Carneiro, J., Castilla, C., Gonçalves Cordeiro, D., Luis Franke, I., Gillison, A., Mansur Mendes, Â., Neves d'Oliveira, M.V., Palm, C., Rodrigues, V., Rossi, L.M., de Sá, C.P., Hermes Vieira, A., Valentim, J.F., Weise, S. and Woomer, P. (2000) Intensifying small-scale agriculture in the western Brazilian Amazon: issues, implications and implementation. In: Lee, D. and Barrett, C. (eds) *Tradeoffs or Synergies? Agricultural Intensification, Economic Development and the Environment*. CAB International, Wallingford, UK.

Vosti, S.A., Witcover, J. and Carpentier, C.L. (2001) *Agricultural Intensification by Smallholders in the Western Brazilian Amazon: From Deforestation to Sustainable Land Use*. Research Report. International Food Policy Research Institute, Washington, DC.

Walker, R. and Homma, A.K.O. (1996) Land use and land cover dynamics in the Brazilian Amazon: an overview. *Ecological Economics* 18, 67–80.

Witcover, J. and Vosti, S.A. (1996) *Alternatives to Slash-and-burn Agriculture (ASB): a Characterization of Brazilian Benchmark Sites of Pedro Peixoto and Theobroma, August/September 1994*. MP-8 Working Paper No. US96-003, International Food Policy Research Institute, Washington, DC.

Wolstein, A.R.P., Lima, E.M., do Amaral, E.F., Braz, E.M., Pinheiro, F.L.N., Franke, I.L., dos Santos, M.H. and Silva, R.F. (1998) *Metodologia Para o Planejamento, Implantação e Monitoramento de Projetos de Assentamentos Sustentáveis na Amazônia.* Documentos, 32, Embrapa–CPAF/AC/INCRA/Funtac, Rio Branco, Acre.