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SOYBEAN CULTIVATION AS A THREAT TO THE ENVIRONMENT IN BRAZIL

Philip M. Fearnside
Department of Ecology
National Institute for Research
in the Amazon (INPA)
Avenida André Araújo, 2936
C.P. 478
69011-970 Manaus, Amazonas
BRAZIL; Study supported by the
Center for Applied Biodiversity Science,
Conservation International

Fax: 55-92-642-8909
Tel: 55-92-643-1822
e-mail pmfearn@inpa.gov.br

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Summary

Soybeans represent a recent and powerful threat to tropical biodiversity in Brazil. Developing effective strategies to contain and minimise the environmental impact of soybean cultivation requires understanding both the forces that drive the soybean advance and the many ways that soybeans and their associated infrastructure catalyse destructive processes. The present paper presents an up-to-date review of the advance of soybeans in Brazil, its environmental and social costs and implications for development policy. Soybeans are driven by global market forces, making them different from many of the land-use changes that have dominated the scene in Brazil so far, particularly in Amazonia. Soybeans are much more damaging than other crops because they justify massive transportation infrastructure projects that unleash a chain of events leading to destruction of natural habitats over wide areas in addition to what is directly cultivated for soybeans. The capacity of global markets to absorb additional production represents the most likely limit to the spread of soybeans, although Brazil may someday come to see the need for discouraging rather than subsidising this crop because many of its effects are unfavourable to national interests, including severe concentration of land tenure and income, expulsion of population to Amazonian frontier, goldmining, as well as urban areas, and the opportunity cost of substantial drains on government resources. The multiple impacts of soybean expansion on biodiversity and other development considerations have several implications for policy: (1) protected areas need to be created in advance of soybean frontiers, (2) elimination of the many subsidies that speed soybean expansion beyond what would occur otherwise from market forces is to be encouraged, (3) studies to assess the costs of social and environmental impacts associated with soybean expansion are urgently required, and (4) the environmental-impact regulatory system requires strengthening, including mechanisms for commitments not to implant specific infrastructure projects that are judged to have excessive impacts.

Keywords: soy, soybeans, deforestation, Amazonia, Brazil, biodiversity

Introduction

International markets for soybeans have been rapidly expanding and the amount supplied by tropical sources has increased even faster than the total volume of global soybean trade, as soy growing has progressively been transferred from temperate to tropical areas where land is cheaper. Latin America is the principal focus of this expansion, especially Brazil, followed by Bolivia and Paraguay.

Soybeans represent a new and powerful force among the panoply of threats to biodiversity in Brazil (Carvalho 1999; Osava 1999).

Effective strategies to contain the advance of soybeans and the damage this advance causes will require both understanding the processes by which the advance occurs and the nature of its impacts. Changing the direction of development can only be expected if decision-makers and the public are aware of the full range of impacts and of the often-indirect means by which they are inflicted.

The decision-making process clearly takes little note of the impacts when major projects are launched. The picture of development that emerges is one of a blind flight towards ever-greater and more widely-dispersed areas of soybeans. Brazil's legal mechanisms for assessing environmental impacts and licensing infrastructure projects are incapable of detecting many of the most severe consequences of soybeans—especially the 'dragging effect' through which other destructive activities (such as ranching and logging) are accelerated by infrastructure built for soybeans. Even when problems are evident despite limitations of the environmental impact assessment system, the system is no match for the lobbying power of soy interests. In addition to the inadequacy of regulatory safeguards, the decision-making process that generates proposal after proposal for grandiose infrastructure projects is effectively disconnected from any consideration of the far-ranging impacts these projects cause. These aspects of the situation should not be taken as givens, but rather as subject to change. Considering the ramifications of the spread of soybeans in some detail provides ample justification for such reforms. The present paper presents a review of up-to-date information on the dynamics and potential impacts of the advance of soybeans in Brazil with a view to identifying appropriate policy responses.

Soybeans and deforestation

The global market for soybeans, which propels the advance of this crop, is really composed of three markets: whole soybeans, soy oil and soy meal. Most meal goes to Europe (to feed poultry and hogs) and most oil to Asia. The global soybean harvest has been rapidly increasing, expanding at 10%/year over the 1989-1998 period (Mendez 1999). China, which was an exporter of soybeans as recently as 1993, is now the world's largest importer in all three markets: whole soybeans, oil and meal (Brown *et al.* 1999). Future demand from China is a major factor in the extent to which soybean cultivation will spread in Brazil.

Much of the soybean planting so far has been in areas outside of tropical forest, such as *cerrado* (central Brazilian scrub savanna) and in various kinds of native Amazonian grasslands (*campos*) (Fig. 1). However, this vegetation harbours a high diversity that is often under-appreciated: Brazilian cerrado is believed to be the most diverse of the world's savannas in terms of number of species (Klink *et al.* 1993; Myers *et al.* 2000).

[Figure 1 here]

The 'dragging effect' and destructive development

The impact of soybeans greatly exceeds the loss of natural areas directly converted to this land use because of the massive infrastructure development needed to provide transportation for harvest and entry of inputs. Other land uses, such as cattle pasture, occupy vast areas but do not carry the political weight needed to induce the government to build up to eight industrial waterways (Fig. 2), three railways, and an extensive network of highways (Fig. 3). Much of the Amazonian portion of the federal government's 1996-1999 'Brazil in Action' (*Brasil em Ação*) programme was devoted to soybean infrastructure (Consórcio Brasiliana 1998; Brazil, Programa Brasil em Ação 1999). The 2000-2003 Pluriannual Plan (PPA), better known as 'Forward Brazil' (*Avança Brasil*), foresees budget allocations for the same infrastructure (Brazil, Programa Avança Brasil 1999, 2000). There are additional existing and planned waterways in other parts of the country, but these are not directly related to soybeans.

[Figures 2 & 3 here]

Much of the effect of the infrastructure projects comes from what Brazilian planners call the 'dragging effect' (*efeito de arraste*), or the stimulation of private investment as a result of public expenditure in a project. According to the head of 'Brazil in Action', the Madeira Waterway is expected to have a 'dragging effect' equal to three times the direct expenditures on the project (Paulo Silveiro, Director, Brazil in Action Programme, public statement 1998). The investments attracted can be expected to include logging, ranching and other activities with severe biodiversity impacts.

The cost to the country of producing soybeans includes not only money invested in infrastructure and in the soy production system. It also includes the opportunity cost of lost environmental services caused by the full impact on natural ecosystems affected by the 'dragging effect', not just what is planted directly to soybeans. The 'dragging effect' completely escapes the current environmental impact statement and project licensing process in Brazil (Fearnside 2000). Costs include biodiversity loss when natural ecosystems are converted to soybeans, severe impacts of some of the transportation systems, soil erosion, health and environmental effects of agricultural chemicals, expulsion of population that formerly inhabited the areas used for soybeans, lack of production of food for local consumption because cropland used for subsistence agriculture is taken over by soybeans, and the opportunity cost of government funds devoted to subsidising soybeans not being used for education, health and investment in activities that generate more employment than does mechanised cultivation of soy. Employment generation by soybean cultivation is minimal. In Maranhão, on average only one worker is employed per 167 ha of soybeans, and on large plantations this ratio rises to one per 200 ha (Carvalho 1999). The employment created often contributes nothing to alleviating local unemployment. For example, in Humaitá, Amazonas, skilled workers from the state of Rio Grande do Sul (Fig. 3) are brought in to operate the agricultural machinery (P.M. Fearnside personal observation).

The rise of soybeans

Brazil produced just under one-quarter of the global soybean harvest in 1998, making it the world's second largest producer—behind the USA, which produces about half the global harvest (Brown *et al.* 1999, p. 32). Brazil's 1999 soy area totalled 13 million ha (Brazil, CNPSO-EMBRAPA 1999). Brazil's long growing season represents a great advantage over competitors in temperate countries. Not only are higher annual yields achieved than in North America, but the extra time in the growing season relieves Brazilian farmers of the exceedingly intense bursts of activity at planting and harvesting times that are necessary for their temperate-zone competitors.

In the 1970s, anchovy fisheries off the coast of Peru collapsed, and this contributed to the use of soybeans as a substitute for fish meal in animal feeds in North America and Europe (see Fearnside 1995). In addition, a drought in North America led to a temporary suspension of shipments to Europe from that major international exporter (Smith *et al.* 1995). The resulting increase in soybean prices led to rapid expansion of mechanised soybean cultivation in the southern Brazilian State of Paraná. A frost in southern Brazil in 1975 also speeded abandonment of coffee. Other factors inducing landholders in southern Brazil to switch from labour-intensive crops such as coffee included increased rights given to sharecroppers under a 1964 land statute and minimum wage laws that increased the cost of hiring labourers (Kaimowitz & Smith 2001).

Soybeans then moved from Paraná to the cerrado (Klink 1995; Klink *et al.* 1994). The march of soybean cultivation {over the last 30 yrs} is shown in maps of data at the level of counties (*municípios*) from the Brazilian Institute for Geography and Statistics (IGBE) (Fig. 4).

[Figure 4 here]

An important factor in the advance of soybeans into the cerrado was development of soybean-bacteria combinations with pseudosymbiotic relationships that allow soybeans to be planted with no application of nitrogen fertiliser. This was a triumph for Brazilian research (e.g. Döbereiner 1992). Development of varieties tolerant to low soil phosphorus and high aluminium was also critical (Spehar 1995).

Generous subsidies were a key factor in inducing the movement of soybeans to the cerrado. The Program for Development of the Cerrados (POLOCENTRO) distributed highly subsidised loans between 1975 and 1982, which were responsible for conversion of 2.4 million ha of savanna to agriculture (Mueller *et al.* 1992). Another key event in the history of the soybean advance in the cerrado was the Nippo-Brazilian Co-operation Programme for Agricultural Development of the Cerrado (PRODECER), begun in 1974 with financing from the Japanese International Cupertino Agency (JICA). This programme has continued, the current PRODECER-III programme being focused on expanding soybeans in the county of Pedro Afonso, in the *Bico de Papagaio* (Parrot's Beak) region in the northernmost part of the state of Tocantins (Carvalho 1999), an area famous for violent land conflicts between small farmers and large *grileiros* (land grabbers) in the 1970s and 1980s (e.g. Foweraker 1981). The large ranchers have now essentially won these battles, having driven small farmers to more distant frontiers. The land is now being converted from cattle to soybean production.

Brazil's overall soybean area declined slightly from 13.2 to 12.7 million ha from 1998 to 1999 (Brazil, CNPSO-EMBRAPA 1999), however soybean-growing continued to shift to Amazonia. In 1996, there were only 1,800 ha of soybeans in Rondônia, but the area increased to 4,700 ha by 1998, and to 14,000 ha in 1999. In Maranhão, the soy area increased from 89,100 to 140,000 ha over the 1996-1999 period (Brazil, CNPSO-EMBRAPA 1999).

The current advance of soybeans into the Amazonian part of Brazil is different from other kinds of land-use conversion in recent years. The role of global markets in soybean expansion is in marked contrast to the dominant land use in deforested parts of Brazilian Amazonia, namely cattle pasture. Cattle ranching has, in the context of Brazilian Amazonia, been largely motivated by ulterior motives such as land speculation, land-tenure establishment, and fiscal incentives (see Hecht *et al.* 1988; Fearnside 1987*a*; in press). Even logging has been, in the Brazilian context, dominated by domestic markets so far (Smeraldi & Veríssimo 1999).

Soybeans have been rapidly expanding in Brazilian Amazonia as a combined result of high prices (still favourable despite recent declines) and indirect government subsidies in various forms, including massive public expenditure on transportation infrastructure such as the *hidrovias* (industrial waterways). Infrastructure projects already built or under construction include the Madeira Waterway, the Itacoatiara soybean terminal, part of the North-South Railway, and the BR-333 Highway linking southern Maranhão to Minas Gerais. Projects not yet built include the Araguaia-Tocantins Waterway, the Teles Pires-Tapajós Waterway, the Capim River Waterway, the North-South Railway (Anápolis—Açailândia), the Ferronorte Railway (Uberaba and Santa Fé do Sul—Vilhena, and later to Porto Velho), the Paraguay-Paraná River Waterway (the 'Pantanal Waterway'), reconstruction of the Madeira-Mamoré Railway and associated development of a waterway on the Mamoré and Guaporé rivers, paving of the Santarém-Cuiabá Highway (BR-163) and construction of the Road to the Pacific. Other plans have been announced that may lead to construction projects further in the future. For example, in 1999, the governor of the State of Amazonas proposed building a waterway to connect the state with the Orinoco Basin in Venezuela (Anon. 1999*a*). Completion of the Boa Vista-Georgetown, Guyana, Highway is also proposed. All of these projects would have substantial environmental impacts.

Because agricultural research provided the key to opening the cerrado to soy cultivation (Paterniani & Malavolta 1999), this is frequently presented in political discourse as proof positive that research will solve the remaining barriers to opening the vast humid tropics of Amazonia to similarly productive agriculture. Patriotic spirit is often claimed as the critical element: a few decades ago no one believed that the cerrado was good for anything, and now it is a great producer of soybeans. The next line in such rhetoric normally goes "If only we believe in Amazonia ...". Unfortunately, more than rhetoric is needed to make sustainable use of the Amazon, although rhetoric is often sufficient to launch grandiose development programs that lead to large-scale destruction for ephemeral rewards (e.g. Fearnside 1986*a*). Severe limits restrain productive use of the very large areas contemplated in Amazonian development plans (Fearnside 1997*a*). These include limits on inputs, such as phosphates, that must be imported from elsewhere (Fearnside 1998). Topography and physical factors are most important for mechanised agriculture, as in the case of soybeans. The best soil in Amazonia on a commercially important scale (*terra roxa*: Alfisol) is usually associated with sloping topography. One question essential to evaluating Brazil's national interest in promoting this land use is whether large-scale soybean cultivation is sustainable.

Some locations contemplated for soybeans have soils with severe limitations. The National Development Bank (Brazil, EMBRAPA 1998: Amazonas, p. 60) cautions that "without well-defined technical criteria" the soil could be rendered unusable by soybean cultivation in the counties of Humaitá, Canutama and Lábrea. This kind of warning is common in discussions of Amazonia development, such as the frequent warnings of EMBRAPA that pastures will produce well in Amazonia only with 'adequate management.' The problem is that everyone involved knows that the 'technical criteria' or 'adequate management' is unlikely to be applied in practice. The result is that later, when problems occur, government agronomists can always point the finger at the farmer for not having used 'technical criteria' or 'adequate management':

the blame is shifted from the government to the farmer for any failures that may occur.

Environmental and social impacts

Impacts of converting land to soybeans

An obvious impact is the loss of natural ecosystems that are converted to soybeans. However, few soybean planters cut forest themselves; instead they buy already cleared land from small farmers who will then move to frontier areas and clear more (Carvalho 1999). Many small farmers who now are threatened with expulsion from their land in Amazonia because of the advance of soybeans came to the region as a result of being expelled from small farms on older frontiers such as Paraná.

When land is converted to mechanised crops like soybeans, most of the human population is expelled, and many move on to deforest elsewhere (Carvalho 1999). In Paraná, soybeans replaced small farmers growing maize, beans and other food crops, in addition to coffee. The rise of soybeans displaced 11 agricultural workers for every one finding employment in the new production system (Zockun 1980). In the 1970s, 2.5 million people left rural areas in Paraná; in the same period, the number of farms declined by 109,000 in Paraná and 300,000 in Rio Grande do Sul (Kaimowitz & Smith 2001). Although most small farmers who were displaced moved to urban areas, many migrated to frontier areas in Rondônia via the new World Bank-financed BR-364 Highway, where they were a key factor in one of the world's most rapid explosions of tropical deforestation activity (Fearnside 1986*b*, 1987*a*).

The Brazilian cerrado has suffered particularly heavy losses to the advance of soybeans. For many years, environmental concerns led to recommendations to favour cerrado as a substitute for rainforest clearing (e.g. Goodland *et al.* 1978). There is some regret of this now that the cerrado is fast disappearing. Remaining areas of cerrado have biodiversity importance that rivals that of equivalent areas of Amazonian forest (Dinerstein *et al.* 1995). The cerrado, with only 1.5% in federal reserves (Ratter *et al.* 1997), is one of the least-protected ecosystems in Brazil. Less protected still is the ecotone between forest and cerrado, a strip that has a higher number of endemic species of plants than either 'pure' forest or cerrado (Fearnside & Ferraz 1995).

Agrochemicals used to combat diseases, insects and weeds in soy cultivation can have impacts on the environment, as well as on the people who are exposed to them. This is a particular concern with respect to plans for expansion of soybeans in the *várzea* (floodplain) near Santarém (Carvalho 1999). During the low-water period, floodplain lakes shrink or dry up, concentrating fish that are easily caught. If the surrounding land is under soybeans, the high doses of agrochemicals used on this crop can be expected to concentrate in the lakes and in the fish.

Soybean cultivation provokes soil compaction and erosion (Barber *et al.* 1996). Aeolean erosion may be particularly severe in Mato Grosso State, but no measurements of losses exist (Jean Dubois, President, Brazilian Network for Agroforestry, personal communication 1999). An idea of the consequences from soil degradation can be gained from the experience in Bolivia. In the area near the city of Santa Cruz, where soybeans have been an important land use since the 1970s, degradation is already severe (Alan Bojanic, former director of Center for Research in Tropical Agriculture (CIAT), Santa Cruz, Bolivia branch office, personal communication 1999). This raises doubts about the long-term sustainability of rapidly-expanding areas in Amazonia, as the soils near Santa Cruz are Entisols that are more fertile than the soils on the Brazilian Shield located in the northern and eastern parts of the Bolivian lowlands, as well as in Brazil. At least initially, soils around Santa Cruz can be cultivated without fertiliser and lime applications, contrasting sharply with soils in Brazilian cerrado and Amazonian forest locations (Alan Bojanic, personal communication 1999). In the late 1990s, over 100,000 ha of soy land was abandoned to cattle pasture because of soil exhaustion, and the three major Mennonite settlements that had farmed the area have moved to clear forest land farther north (Alan Bojanic, personal communication 1999). The area of relatively fertile soils is rapidly coming to an end for further movement of this mechanised version of shifting cultivation.

Because soybeans require heavy capital investment in machinery, land preparation, and agricultural inputs, this crop is inherently the domain of wealthy agribusiness entrepreneurs rather than poor farmers. Extreme income concentration has been associated with soybeans wherever they have spread in Latin America (Kaimowitz *et al.* 1999). Income concentration and the associated political influence of powerful elites have negative repercussions throughout societies where these transformations are taking place.

Short-term plans for infrastructure

Road to the Pacific

Plans for soybean production in the state of Acre are given as a justification for building the Road to the Pacific, either via Assis Brasil (in southern Acre) and Cuzco, Peru, or via Cruzeiro do Sul (in western Acre) and Pucallpa, Peru (Fig. 3). However, the economic viability of transporting soybeans across the Andes by truck has yet to be shown. Lack of economic viability does not imply guaranteed protection of the environment from such projects. Whether or not soy export via the Andes is economic, it can provide an excuse for expensive public works to go forward, propelled by the financial interests of construction contractors and by electoral use of the project. The Balbina and Jatapu Dams provide well-documented examples (Fearnside 1989; Fearnside & Barbosa 1996).

Infrastructure projects implanted with the primary purpose of transporting soybeans will have effects on the economic attractiveness of other commodities, with consequent impacts on the environment. Timber export from Acre on the Road to the Pacific provides an example.

Paraguay-Paraná (Pantanal) Waterway

Impacts of the Paraguay-Paraná Waterway (Fig. 2) would be substantial, posing a threat to the wildlife and general biodiversity of the Pantanal (Blumenschein *et al.* nd [1999]; Hamilton 1999), and the portion of the waterway from Corumbá to Cáceres would be the worst stretch in the region (Buscher & Huszar 1995).

The Brazilian government announced in March 1998 that it was dropping plans for the Paraguay-Paraná Waterway (e.g. Associated Press 1998). This kind of announcement provides only fragile protection from damaging projects of this kind, as recently made clear by the case of the Babaquara Dam on the Xingu River. Since 1992 government officials have made innumerable statements declaring that this dam will not be built, but now it has appeared with a new name (the Altamira Dam) in the current decennial plan (Brazil, ELETROBRÁS 1998, p. 148) with completion scheduled for 2013. The problem is that we lack a legal mechanism by which the government can make irrevocable commitments *not* to build specific projects that are known to be damaging. Like Babaquara, the Corumbá-Cáceres stretch of the Pantanal Waterway has now quietly resurfaced with inclusion in the ‘Forward Brazil’ portfolio (Consórcio Brasiliana 2000) and with work on a new port facility near Cáceres (Switkes 2000).

Tocantins-Araguaia Waterway

The Tocantins-Araguaia Waterway (Fig. 2) would expose Bananal Island, the site of both the Araguaia Indigenous Park and the Araguaia National Park, to wave action, and would negatively affect fisheries in the river (Cohen 1995; Switkes 1999). The environmental impact study (EIA) and environmental impact statement (RIMA) for this waterway (FADESP 1996*a*,*b*) omitted portions of the original text that mentioned expected increases in mortality in tribes in the Araguaia Indigenous Park due to the effect of pollution and barge traffic on fisheries resources. This has led to accusations by the anthropologists who worked on the EIA that the version of the EIA and RIMA reports submitted to the Brazilian Institute of the Environment and Renewable Natural Resources (IBAMA) was 'unscrupulous and in bad faith' (Carvalho 1999). Multiple failings in the RIMA led to a court order in June 1997 suspending work on this Waterway (Switkes 1999). Among other failings, there is no mention of what would be done with 2.5 million m^3 of sediment to be dredged from the river and 204,000 m^3 of rocks to be exploded (Novaes 1998). The report failed to mention that the river is too dry to navigate from June to November, the time of year when soybeans would be harvested. It assumed transportation of 30 million tonnes of soybeans per year, which is six times the current production of Mato Grosso, and, without naming a single product, supposed that the barges would carry return freight equal to 50% of this capacity (Novaes 1998). The waterway would compete with the North-South Railway for transporting production from many of the same soy-producing areas. The public hearing for the Waterway was suspended on 22 September 1999 by a judicial ruling in favour of the anthropologists who had been misrepresented in the report (Silveira 1999). On 29 September, the construction consortium obtained a counter-ruling, allowing preparations for the waterway to proceed (Radiobrás 1999). The Tocantins-Araguaia Waterway continues to be a priority project under the 'Forward Brazil' programme (Consórcio Brasiliana 2000).

The Tocantins-Araguaia Waterway would include installing shiplocks in Tucuruí Dam and in a long series of planned hydroelectric dams on those rivers (Fearnside 1999). The path of the waterway includes a 925-m change in elevation. The question of how decisions will be reached on whether to install locks in dozens of dams is a delicate one, as Brazil's Minister of Development since 14 September 1999 had, until his appointment, been president of the Camargo Corrêa construction company (Anon. 1999*b*). At the time of his appointment, Camargo Corrêa was already installing locks in the first dam (Tucuruí) and was best positioned to obtain all of the contracts along the Tocantins-Araguaia Waterway.

Teles Pires-Tapajós Waterway

Work on the Teles Pires-Tapajós Waterway (Fig. 2) was suspended by a court order in June 1997 because its EIA omitted mention of impacts on indigenous people along the route (Novaes 1998). Impacts on the Mundurucu tribe were omitted by a division of the report into two sections, one for the stretch below the tribe and the other for the one above it, and simply neglected to make any mention of the existence of the tribe (Novaes 1998). Omitting mention of the Indians was a means of avoiding the constitutional requirement of obtaining project approval from Congress.

Madeira Waterway

In March 1997, barges began to arrive in Itacoatiara, Amazonas, at a new soy terminal that had been largely paid for by the state government (Anon. 1997*a*). The warehouse has storage capacity for 90,000 tonnes, and in a second phase, this will be doubled (Luís Antônio Pagot, Director, HERMASA Navegação da Amazônia, S.A., public statement 1997). Since the terminal began operation, 145 trucks per day have been arriving in Porto Velho (Fig. 3) loaded with soybeans. Soybeans are transferred to barges to go down the Madeira River to the port of Itacoatiara, where they are stored and loaded on ships for export. This new export route has cut the transport cost by a factor of three (Luís Antônio Pagot, public statement 1997), thereby radically changing the economic context for agriculture in the Madeira River basin.

For the time being, the soy comes from savanna areas in Mato Grosso State, especially Sapezal, at the centre of the Maggi soy empire (Vieira & Giraldez 1999). However, the government of Amazonas State is giving priority to promoting soybeans and irrigated rice in the *campos de Humaitá*, a natural grassland in the southern part of Amazonas (Anon. 1997*b*). The classic study on soils of the campos de Humaitá condemned this area for agricultural development due to the laterisation danger (Gross Braun & de Andrade Ramos 1959). Although the danger of widespread laterisation in Amazonia has often been exaggerated, in places where the water table fluctuates the danger is real (Sánchez 1976). Soils in the campos de Humaitá have impeded drainage, causing the water table to fluctuate close to the surface (Fearnside 1997b).

The Maggi group, which installed the port, plans to expand its plantations in the campos de Humaitá, provided that it is permitted by the economic-ecological zoning of the area, now being effected by the state government (Luís Antônio Pagot, public statement 1997). Maggi has conducted agricultural experimentation at the site since 1993, and the belief is that laterisation would not be a problem because soil can be drained by installing canals which would lead the water to the streams (Luís Antônio Pagot, public statement 1997).

The Waterway and soy terminals bring little local benefit. The Itacoatiara terminal employs only 17 people (Osava 1999). Tax benefits are also minimal because, since 1996, Complementary Law No. 87, better known as the ‘Kandir Law’, has exempted products bound for export from paying the tax on services (ISS) that would otherwise go to the county governments (Carvalho 1999). Prior to the exemption, Brazilian soybean growers were at a disadvantage compared to their Bolivian competitors, who paid US$37.17/t less in taxes (Monitor Company 1994).

The Madeira Waterway provides a good example of a generic problem with infrastructure projects of this kind, namely, evolution of the projects after construction has begun, leading to greater impacts than those considered in the original EIA and RIMA. In practice, pressure generated by the economic activity already all but guarantees approval of any request for additional infrastructure. After soybean shipments began, HERMASA (the barge company owned by Maggi) requested that the Rondônia state government allow shortcutting a sharp bend in the Madeira River downstream of Porto Velho, which would cut through the Cuniã Lake at the Cuniã Ecological Station, a protected area. The cut could lead to draining the wetlands and riverine lakes that harbour the abundant wildlife for which the ecological station was created. Plans for river straightening were not included in the proposal considered by the current EIA and RIMA for the Waterway, which was approved in 1999. The planned increase in barge traffic from an initial 300,000 t/year to 3 million t/yr by 2000 (HERMASA 1995, cited by Blumenschein *et al.* nd [1999]) implies need to both straighten the riverbed and remove the rock obstructions along the route. The EIA and RIMA only covered removal of three rock obstructions. Without these modifications, the Waterway is only passable during the high-water period. The total number of obstructions that would need to be removed has been variously stated as six (Luis Antônio Pagot, public statement 1997) to nine (Blumenschein *et al.* nd [1999]).

Boa Vista-Georgetown Highway

A proposed all-weather highway from Boa Vista to Georgetown, Guyana, would provide a 600-km route for export from Roraima, the governor of which is attempting to attract soybean growers from the south and central-west regions of Brazil by offering such inducements as exemption from all taxes for 20 years, the cheapest land in Brazil (US$5-50/ha), and the services of a government-sponsored co-operative (COOPERNORTE) (Veríssimo 1999). In August 1999, the Roraima state government chartered an aeroplane to fly 60 prospective investors to the state; the goal was to invest US$300 million over five years and to have 200,000 ha of soybeans in Roraima by 2003 (Veríssimo 1999). Like the Road to the Pacific, although the arguments for the Boa Vista-Georgetown Highway are largely based on soybeans, much of the project’s environmental impact would probably be felt through effects on other commodities. In this case, the notoriously-destructive Malaysian logging companies with concessions in Guyana are likely to be major beneficiaries (cf. Colchester 1994; Veening & Groenendijk 2000).

Santarém-Cuiabá Highway

A 75,000-tonne capacity soybean terminal at Santarém, Pará, began operation in May 2000 (see Carvalho 1999). Plans for producing soybeans include paving the Santarém-Cuiabá Highway (BR-163), part of 'Forward Brazil' and improvement of the waterway from Itaituba to Santarém (Fig. 3), where soybean planting would also be promoted in the varzea.

The Santarém-Cuiabá Highway is an area that is already a major source of illegally cut mahogany (Fearnside 1997*c*). Political pressure for paving the road is led by Blairo Maggi, senator from Mato Grosso and head of the Maggi Group that is financing soy planting in Santarém and construction of the Santarém and Itaituba soy terminals. The campaign included a *caminhonaço* (truck caravan) travelling along the route in May 1999 to demonstrate the viability of exporting soybeans from northern Mato Grosso through the port of Itaituba (Vieira & Giraldez 1999).

Capim River Waterway

The Capim River Waterway would give barge access to the Paragominas soybean pole, connecting it with the deepwater port in Barcarena.

North-South Railway

The North-South Railway would connect Goiânia in Goiás State, with Açailândia in Maranhão, where it would connect with the Carajás Railway leading to the ports of Itaiquí and Ponto da Madeira near São Luís (Fig. 3). The Carajás Railway has been functioning for iron-ore transport since 1984. Part of the North-South Railway was built in 1988 but was halted as a result of a major financial scandal.

Ferronorte Railway

The portion of the Ferronorte Railway included in the 'Forward Brazil' Programme would connect Uberaba and Uberlândia, in Minas Gerais to Cuiabá, Mato Grosso, and then with Vilhena, Rondônia (Fig. 3). The railway will also connect to the rail network in the State of São Paulo (FEPASA) at Santa Fé do Sul. The route would pass through major soybean areas such as Rondonópolis. Construction of the bridge over the Paraná River was completed in January 1998.

Other Highways

In 1996 the 450-km MT-235 Highway was completed cutting across the Chapada dos Parecis of Mato Grosso from east to west from Comodoro to Sapezal and Campo Novo dos Parecis (Fig. 3).

Large areas were cleared for soybeans along the route in its first year, in anticipation of export via the Madeira Waterway (Blumenschein *et al.* nd [1999]).

Highways from Maranhão to Minas Gerais link the major soybean production area around Balsas, in southern Maranhão, with the road system in Minas Gerais, also providing access to agricultural areas in state of Piauí. These highways, which were paved for soybean transport under the World Bank's highway improvement loan for Maranhão, Piauí and Tocantins, pass through the best-preserved area of remaining cerrado vegetation, according to the Brazilian Institute of Space Research (INPE) study of 1992 and 1993 satellite images that found 65% of the cerrado had been cleared for pasture, agriculture and urban settlements by that time (Mantovani & Pereira 1998, cited by Stedman-Edwards 1999).

A road construction and soybean project in Apuí on the Transamazon Highway in the south-east corner of the State of Amazonas is of particular concern both for its potential impacts and for the extent to which this case has revealed the inability of Brazil's environmental regulatory mechanisms to function in practice. The municipal government of Apuí and the government of the adjacent county in Mato Grosso began building a road to connect the two (Anon. 1999*c*). The road, which is not part of 'Forward Brazil', was being built without any form of environmental impact statement or approval, and was halted by the Amazonas state environmental agency in September 1999 (Anon. 1999*d*). Brazil's constitution and legislation require an EIA and RIMA for all highways. However, no criteria of what constitutes highway construction, as opposed to improvement, are given. In practice, proponents can claim that even an illegal logging track through the forest can be upgraded by degrees to a paved thoroughfare without being considered highway 'construction' (Francisco Arguelles, Public Ministry of the State of Amazonas, Specialized Prosecutor's Office for Defense of the Environment and Historical Patrimony (PRODEMAPH), Manaus, personal communication 1999).

The road from Aripuanã in Mato Grosso, to Apuí in Amazonas, will connect with an existing road connecting Apuí to the port of Novo Aripuanã in Amazonas, on the Madeira River (Fig. 3). This road was built without benefit of an EIA and RIMA by claiming that it was merely improving access roads to settlements implanted by the National Institute of Colonisation and Agrarian Reform (INCRA). The two roads would reduce the distance that soybeans must travel by truck from production areas in north-western Mato Grosso. The Maggi Group is reportedly helping with construction of the Aripuanã-Apuí road and with improvement of the Apuí-Novo Aripuanã Road. The Soybean Producers Co-operative of Amazonas (COPASA), which is led by Maggi, is attempting to obtain title to 850,000 ha of *terras devolutas* (government land) in the county of Novo Aripuanã (Fachel 1999). COPASA publicly encouraged farmers to clear new areas as quickly as possible between December 1998 and August 1999 so that the areas could be used for soy planting (Carvalho 1999). Maggi has promised to buy all soybeans produced by the co-operative (Carvalho 1999). COPASA has encouraged migrants to come to the area to clear, and a total of 85,000 ha has been deforested so far (Fachel 1999). It is unclear what will become of the migrants once the land is converted to soybeans, since employment in soybean production is minimal.

Long-term plans for infrastructure

It is unlikely that funding for all of the infrastructure described in the 'Forward Brazil' Programme will become available within the 2000-2003 time span of the programme. However, one can expect the same overall plan to be maintained while the time scale is extended to conform to funding restrictions. Beyond the 'Forward Brazil' Programme, a number of additional soybean transportation projects are planned (Table 1). Each of these would have substantial environmental impacts.

[Table 1 here]

Impacts of soy-related industries

Processing industries and other activities associated with soybeans can also have impacts, especially by stimulating expansion of plantations. Brazil's soybean-crushing mills are mainly located near the older producing areas in the southern part of the country. Additional crushing facilities are being planned, including one in Itacoatiara, Amazonas, with Venezuelan capital (Anon. 1999*a*). The 'sunk costs' of industrial and storage facilities was a major factor empowering Brazil's soybean lobby in the 1980s in their efforts to gain additional government subsidies for expanded planting. In 1982 Brazil's processing capacity was double what was needed for the size of the soybean crop because of incentives that had been given for processing facilities (Williams & Thompson 1984).

Since a large part of Brazil's soybean harvest is shipped to Rotterdam and then fed to European pigs, Holambra (a Dutch agribusiness firm in São Paulo) proposed settling a colony of Dutch pig farmers in Mato Grosso. This would obviously eliminate much of the transportation required by the current arrangement. It should be remembered that industrial-scale swine raising produces substantial pollution from manure and urine, as is now occurring in the Netherlands. Brazil's swine industry, which is concentrated in Santa Catarina State, has the same problems.

Another Dutch proposal foresaw shipment of manure from the Netherlands to Amazonia, using the return journey of the ships that bring soybeans to Rotterdam. The manure would be used as fertilizer in Amazonia. While the proponents of the scheme envisage manure increasing the sustainability of Amazonian agriculture and reducing deforestation, the result would probably be more complex. Increasing the profitability of agriculture normally has the opposite effect on deforestation (Fearnside 1987*b*). The plan has apparently not advanced due to opposition by Brazilian non-governmental organisations concerned over possible contamination by heavy metals and growth hormones (Wim G. Sombroek, International Soils Reference Information Centre (ISRIC), Wageningen, the Netherlands, personal communication 1999).

Future prospects: dynamics of soybean expansion

Lobbies and subsidies

Lobbies operate at federal, state and municipal levels. State-level development decisions are strongly influenced by soybeans. In Maranhão, for example, the head of planning in the state government has a rapidly expanding soybean empire in the Balsas area of the state. Pending decisions include revoking part of the Serra do Mirador (Itapecuru) State Park, in the upper Itapecuru Valley of Maranhão. A part of the park that is suitable for soybeans would be exchanged for protecting areas elsewhere in the state (Afonso Henriques de Jesus Lopes, Coordinator for Maranhão, Natural Resources Sub-Program (SPRN), Pilot Program to Conserve the Brazilian Rainforest (PP-G7), São Luis, Maranhão, public statement 1999).

In Maranhão, the babassu palm (*Attalea*, formerly *Orbignya* spp.) has traditionally been a source of oil and a variety of other products. Improving industrial means of using these palm fruits has long been a priority for sustaining the local population living from babassu extractivism (May 1990). The State Institute of Babassu (INEB) was created by the government of Maranhão for this purpose, but after only four years it was abolished in 1984. In Maranhão, it is widely believed that the reason was the governor’s financial interests in soybeans (personal observation), with which babassu was still competing, at that time, as a source of oil in the local market.

Family agriculture in Maranhão is rapidly retreating before the advance of soybeans, aggravating social disparities in a state that is already notorious for poverty and social inequalities (Carneiro 1999). Maranhão is also one of the largest sources of migrants to Amazonia, supplying population to both pioneer settlement areas and the goldrush in *garimpos* (wildcat mining areas) (e.g. Cleary 2000; MacMillan 1995). Goldmining causes severe environmental and social impacts, including mercury pollution, release of large quantities of sediment into the headwaters of Amazonian rivers, and invasion of indigenous lands, exposing the Indians to disease, violence and deculturation, as well as impeding the recognition and demarcation of reserves (e.g. Cleary 2000).

The expulsion of population from Maranhão has also led to deforestation by landless migrants in Amazonia, as well as supplying the largest source of cheap labour used by Amazonian ranchers for their clearing. Of 19 landless peasants massacred by federal police at Eldorado dos Carajás, Pará, in 1996, seven (37%) were from Maranhão (Anon. 1996).

State governments have been instrumental in promoting the rapid entry of soybeans into Amazonia. In Amazonas State, an agricultural promotion scheme that includes the Humaitá soybean and irrigated rice areas was a centrepiece of the governor's campaign in the 1998 gubernatorial election. Establishing soybean areas in Humaitá would have been unlikely without the wide range of subsidies given by the state. Fertilizer was brought from Israel by the state government and distributed with payment due only after the harvest. Fertilizer from Cubatão, near Santos, São Paulo (3340 km away) would cost US$200/t (Brazil, EMBRAPA 1998: Amazonas), considering the mid-1999 exchange rate of R$1.7 = US$1. Lime, which does not exist in the Humaitá area, was brought by truck from Pimenta Bueno, Rondônia (700 km away) and distributed free of charge. Lime in Pimenta Bueno costs US$7.05/t, and freight to Humaitá is US$22.94/t. The capacity of the Pimenta Bueno deposit is 266 million t (Brazil, EMBRAPA 1998: Amazonas, p. 65). The next nearest deposit is in Cáceres, Mato Grosso (1440 km away), where lime costs US$6.47/t and freight to Humaitá is US$29.41/t.

Lime is now being shipped to Humaitá by barge from Urucará on the Jatapu River (1000 km by river) (Fig. 3); the capacity of the Urucará deposit is 48 million tonnes. The next nearest deposit accessible by river is in Maués, Amazonas (1200 km by river), with a capacity of 175 million tonnes (Brazil, EMBRAPA 1998: Amazonas, p. 66).

Lime, and its transportation, is generally considered the main expense in establishing soybean cultivation in Amazonia. The Humaitá soybean pole is extreme in having no lime deposit nearby. The pole in Redenção, Pará, has a lime deposit considered to be of poor quality (Carvalho 1999). The pole at Santarém benefits from a large lime deposit near Itaituba (Fig. 3). Apuí in Amazonas has a lime deposit in the county that is not yet developed; poor road conditions between Apuí and Humaitá have kept this deposit from entering current plans for supplying the Humaitá soybean pole (Brazil, EMBRAPA 1998: Amazonas).

Lime must be reapplied every three years. The lime requirement is 4-8 t/ha if calculated on the basis of aluminium saturation (Brazil, EMBRAPA 1998: Amazonas, p. 62). If lime requirement is estimated considering calcium and magnesium in addition to aluminium, the requirement is 7-8 t/ha (Brazil, EMBRAPA 1998: Amazonas, p. 62). Less-massive lime requirements represents one of the inducements for movement of soybeans into Amazonia, as less lime is required in recently cleared forest as compared to cerrado. In forest, 2 t/ha of lime are required, versus 4-6 t/ha in cerrado (Homma & Carvalho 1998).

The government subsidy for soybeans goes beyond the visible infrastructure planned under programmes such as 'Forward Brazil', which is the flagship of the current presidential administration. Agricultural credit for purchase of inputs, such as seeds and chemicals, and especially for tractors and other machinery, is given at rates well below those that would apply on the basis of standard financial calculations, especially if the risk of default is taken into account. Brazilian agricultural credit has long been heavily influenced by lobbies from large producers, and soybeans have been a favourite crop because the large farmers who produce them have secure land titles, collateral, and lower transaction costs for banks (Helfand 1999, p. 7). Because soybean prices are subject to fluctuations, and because bad weather, insects, and other misfortunes may reduce production, farmers often find loans financially difficult to repay. Since price cycles and agricultural problems affect all farmers simultaneously, the farm lobby (known as *ruralistas* in Brazil) represents a significant interest group to apply on the government to make special concessions. On several occasions, the government has simply cancelled all agricultural debts, amounting to a subsidy that often totals tens of billions of US dollars to the agricultural sector. In 1999, pressure from the farm lobby led to a partial amnesty of the year's agricultural debts (Provisional Measure 1918) that will cost an undisclosed amount considerably higher than the US$4 billion cost of the previous agreement with the farm lobby (Anon. 1999*e*).

The soy lobby is credited with obtaining federal subsidies allowing soybeans to expand into areas that were more distant and had poorer soils than would have been justified in the absence of subsidies (Kaimowitz & Smith 2001). Particularly important is northern Mato Grosso, where environmental impacts of soybean expansion are particularly strong. In addition to subsidized credit, in the mid-1980s the federal government maintained the Minimum Price Guarantee Policy (Goldin & de Rezende 1993). This meant that farmers received the same price regardless of their location, encouraging expansion to distant frontiers where market forces would otherwise have rendered soybeans unprofitable (Kaimowitz & Smith 2001). In the 1980s, another subsidy to distant plantations was Brazil's unified price for petroleum products, where the same price for fuel was charged throughout the country. Transport to and from far-flung locations thereby received a subsidy from fuel consumers located near Brazil's ports and oil refineries.

Rarely discussed is the opportunity cost of government money that is spent to subsidise soybeans. Clearly many uses for money exist that would have much greater returns for the welfare of the Brazilian people. One cannot know how much of such money would actually go to health, education, environment and other areas that would produce greater social benefits were the funds not used for soybeans. There is also a large environmental opportunity cost of sacrificing natural ecosystems such as Amazonian forest (Fearnside 1997*c*).

The transgenic seeds controversy

The close link of soy cultivation to agribusiness-controlled genetic engineering is an additional source of controversy. The Brazilian government approval of use of transgenic soybeans would open the way for Monsanto's Roundup-Ready™ soybean seeds. The genetically-engineered Roundup-Ready™ seeds are resistant to Roundup™ herbicide, or glyphosate, which is also manufactured by Monsanto. Roundup™ kills most other plants, including neighbouring farmers' non-resistant soybeans, creating an additional motivation for all to make the switch together. A wide variety of doubts have been expressed concerning the potential impacts of releasing genetically modified (GM) organisms into the environment (e.g. Halweil 1999; Labes 1999). The discovery that monarch butterflies can be killed by pollen from transgenic maize (Losey *et al.* 1999) has heightened concern for the lack of understanding of potential impacts; the contrast with the great care taken in introducing new pharmaceutical products is very plain.

Glyphosate herbicides are allegedly linked to reproductive disorders, genetic damage, liver tumours and developmental delays in mammals (Cox 1999; Labes 1999). These chemicals are also considered to adversely affect earthworms, beneficial soil fungi and nitrogen-fixing bacteria (Cox 1999). On the positive side, herbicide use reduces the need for plowing, with attendant soil compaction, erosion and carbon stock depletion.

Brazilian soybean areas can be expected to be dominated by Roundup-Ready™ soybeans within a year or two after approval is obtained. In September 1998, Brazil's National Technical Commission on Biotechnology approved transgenic soybeans for planting in the country, but Brazilian non-governmental organisations obtained a judicial ruling in June 1999 requiring an EIA for transgenic soybeans (Arnt 1999). Prior to the ruling, Monsanto expected that 50% of Brazil's 13 million ha of soybeans would be converted to Roundup-Ready™ seeds by 2002 (Labes 1999). The technological package for this variety results in higher yields at reduced cost under current price regimes. It bears mentioning, however, that this transformation will give Monsanto an effective monopoly over a series of essential inputs in the soybean production process, thereby increasing the chance that prices of these inputs will be raised to the maximum level that the market will bear once the monopoly has been consolidated.

At the least, a switch to transgenic soybeans in Brazil will make soy cultivation more profitable and so speed the crop’s advance into Amazonia. On the other hand, if Brazil does not approve use of transgenic crops and demand for non-transgenic soy in Europe results in a premium price, then this too could speed the advance of soybean growing in Amazonia, an effect that is already evident (Carvalho 1999).

Limits to the spread of soybeans

How far will soybeans go? The answer depends on the new equilibrium between supply and demand. It also depends on the point beyond which each country considers further expansion of soybeans to be contrary to national interest, in view of the environmental and social impacts of this land use.

Discussions of Brazil’s national interest in soy production are confused by the terminology adopted. EMBRAPA and other agencies active in promoting soybeans scarcely even use the term ‘soybeans’ (*soja*), using instead the term *grãos* (a term without an exact English equivalent, referring to any crop where the useful part is the seed, including both grains and pulses). The difference between soybeans and grãos is much more than semantic. Like *agro-pecuária* (literally ‘agro-ranching’), the euphemism for cattle ranching in Amazonia, calling soybeans grãos serves to convey the implication that soy is feeding the people of Brazil along with rice, maize and wheat. In reality, soybean expansion is much more akin to Brazil’s long history of predatory exploitation of natural resources, such as Brazilwood in the Atlantic forest, and minerals in Minas Gerais, than it is to agriculture growing food crops for local consumption. Maize is often emphasised in discourse over grãos in Brazil. Maize is indeed usually part of the crop rotation cycle used with soybeans, but economically it is only a by-product. Only soybeans justify the massive infrastructure that gives this commodity such a substantial impact on biodiversity.

While a vision of soy feeding Brazilians is often implied in discourse on the subject, Brazilians like to eat rice and beans, not soy. Although some soy is consumed in the form of cooking oil, this part of the harvest could easily be supplied by existing soybean areas in Brazil. The further expansion of soybeans is entirely as an export crop.

Figure 5 illustrates factors affecting the areal extent of soybean cultivation in Brazil. The feedback of areas planted to prices represents an important controlling factor; Brazil’s soybean production is sufficient to have an important impact on global prices for this commodity (Frechette 1997). Decision-making on government policy regarding subsidies may seem remote from the reality of how decisions are taken in practice on such problems, but it is important to realise that a decision by default is, in fact, being taken every day (Fig. 5). Business-as-usual does not just happen: it is the result of a tacit decision to leave policies unchanged. The consequences of this decision, and of alternatives, must be understood and faced.

[Figure 5 here]

In 1998, high humidity after rains meant that Roraima soybeans were struck by the *Rhizoctonia* fungus that, in beans, produces *mela*, the much-feared web-blight disease (de Andrade 1999). Similarly, high humidity in the varzea soybean area planned near Santarém is expected to carry a greater risk of disease than in dry areas like the cerrado, leading to increased fungicide use (Carvalho 1999). *Rhizoctonia* attack in soybeans is facilitated by the presence of weeds (Black *et al.* 1996). High rainfall and lack of dry periods represent a source of concern for sustainability of soy cultivation in the western part of Brazilian Amazonia (e.g. de Andrade 2000).

On 24 June 1997, President Fernando Henrique Cardoso announced in his weekly radio programme *Palavra do Presidente* (‘The Word of the President’) that six million hectares along the BR-174 (Manaus-Caracaraí) Highway (Fig. 3) would be opened to settlement, and suggested that the area farmed there would be ‘so colossal that it would double the nation's agricultural production’ (de Cássia 1997). Despite almost certain hyperbole in both the expected production and area likely to be settled, the intention of initiating a major program on the BR-174 Highway appears to be real (Fearnside & Leal Filho 2001). The announcement of the BR-174 settlement programme came as a surprise, as paving of the highway in 1996-97 had been presented as a surgical cut through the forest that would allow the city of Manaus to trade with Venezuela and have access to that country's ports.

Announcements like President Cardoso’s radio broadcast need to be interpreted with a certain amount of scepticism, but they often forebode major projects preceding detailed plans. One generic problem in Amazonian development projects is that political pressure to carry out the projects is generated before the environmental and social impacts of the projects are analysed and judged. Public works are announced as government commitments before the EIA and RIMA are prepared, thereby making it difficult, in practice, to stop projects even when impacts are severe.

Apart from announcements, it also takes adequate market demand and infrastructure to transport the beans, and lime and other required inputs, to make great areas of soybeans appear. The extent to which the rapid expansion of global soybean markets that has occurred over the past decade will continue is critical. A major question is whether China will increase its imports of soy.

Because soybean expansion in the USA is believed to be approaching its limits, much of the increased demand from China is likely to be met through expanding areas in Latin America. The level of government subsidy to soybeans in the USA is also a factor, as any decrease in these subsidies would result in transfer of soy growing to Latin America.

Human decisions, particularly Brazilian government decisions, will determine to a large degree how soybeans will advance in Brazil, and to what extent the advance will continue before a new equilibrium is reached. Clearly the area in soybeans will not simply go on expanding until this crop occupies the whole country. The advance can eventually be expected to stop when supply exceeds global demand sufficiently to cause prices to fall to levels low enough that further expansion of soybeans becomes unprofitable. Before that point is reached, however, Brazil might well decide that more expansion of soy-growing areas is not in the national interest. Reasons include feedback to prices affecting the profitability of soybean growing throughout the country, the substantial financial drain that government subsidies for soybeans represents to the budgets of federal, state and municipal governments, and the social and environmental costs of converting ever-larger areas to soybeans. Governments might therefore decide to curtail subsidies before soybean expansion halts by itself under the current set of economic drivers. One might even imagine governments taking active measures to discourage further expansion of soybeans if it were perceived to be damaging, but, at present, this is far from the case, with governments at all levels vying to attract as much soy investment as possible.

What is needed is an honest weighing of costs and benefits of expanding soybean cultivation, including all social and environmental costs. Only then can countries like Brazil take rational decisions as to how much soybean expansion is in each country’s national interest, and with what infrastructure.

Conclusions and recommendations

The multiple adverse impacts of soybean expansion on biodiversity will be mitigated, and other development considerations substantially addressed, if the following actions are taken by policymakers and acted upon:

(1) Create protected areas in advance of soybean frontiers;

(2) Encourage elimination of the many subsidies that speed soybean expansion beyond what would occur otherwise from market forces;

(3) Rapidly carry out studies to assess the costs of social and environmental impacts of soybean expansion, including opportunity costs of money and land;

(4) Strengthen the environmental-impact regulatory system, including assessment of the indirect impacts (the 'dragging effect') of infrastructure in stimulating other economic activities that are often destructive;

(5) Create mechanisms such that commitments can be made not to implant specific infrastructure projects that are judged to have excessive impacts; and

(6) Encourage decision-making based on the full roster of costs and benefits, in contrast to the present system exemplified by the 'Forward Brazil' Programme.

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FIGURE LEGENDS

Figure 1 – Original vegetation types in Brazil, including areas threatened by soy development in the Pantanal wetlands, Amazonian forests, cerrado savannas and 'other' Amazonian savannas.

Figure 2 – Industrial hidrovias (waterways) for soybean transport. Waterways 1, 4 and the southern part of 5 are partially operational; 2 and 3 are in advanced stages of the licensing process; the northern part of 5 is a latent 'vampire project' (see text), and 6, 7 and 8 are in preliminary stages of discussion.

Figure 3 – Locations mentioned in the text.

Figure 4 – Soybean cultivation in (a) 1977, (b) 1990, (c) 1996. Areas of circles are proportional to soybean areas by municipio (county). (After Théry 1999).

Figure 5 – Factors affecting soybean expansion in Brazil. In causal loop diagrams such as this, the sign near the head of each arrow represents the direction of change in the quantity at the head of the arrow given an increase in the quantity at the tail of the arrow.

Table 1 Beyond ‘Forward Brazil’: Long-term Plans for Soy Infrastructure

Project	Starting location	Ending location	Status
Road to the Pacific	Rio Branco, Acre	Una, Peru (a)	Announced as a goal by President Ferrnando Henrique Cardoso, Only the Brazilian portions (Sena Madureira–Cruzeiro do Sul and Rio Branco–Assis Brasil) are included in the Forward Brazil program.
Rio Branco Waterway(b)	Itacoatiara, Amazonas	Boa Vista, Roraima	Appears on Ministry of Transportation maps (Brazil, Ministério dos Transportes 1999), but not included in Forward Brazil.
Açaílândia–Belém Railway	Açaílândia, Maranhão	Belém, Pará	Appears on Ministry of Transportation maps (Brazil, Ministério dos Transportes 2000), but not included in Forward Brazil.
Cuiabá–Santarém Railway	Cuiabá, Mato Grosso	Santarém, Pará	Appears on Ministry of Transportation maps (Brazil, Ministério dos Transportes 2000), but not included in Forward Brazil.
Cuiabá–Porto Velho Railway	Cuiabá, Mato Grosso	Porto Velho, Rondônia	Appears on Ministry of Transportation maps (Brazil, Ministério dos Transportes 2000), but not included in Forward Brazil.
Madeira–Mamoré Railway	Guajará-Mirim, Rondônia	Porto Velho, Rondônia	
Guaporé–Mamoré Waterway	Vila Bela de Santíssima Trindade, Mato Grosso	Guajará-Mirim, Rondônia	

Orinoco–Rio Negro Waterway	Itacoatiara, Amazonas	Puerto Ayacucho, Venezuela	Announced by Amazonas state governor Amazonino Mendes (Anon. 1999a)

(a) May be either via Assis Brasil, Acre and Cuzco, Peru, or via Cruzeiro do Sul, Acre and Pucallpa, Peru.

(b) Maggi plans to plant 500,000 ha of soybeans in Roraima if the Rio Branco Waterway proves feasible (Gonçalves 1998). In addition, the '*Grãos Norte*' Programme hopes to increase the area of soybeans in the state from near zero in 1999 to 200,000 ha in 2005 for export soybeans by road via Venezuela (Mary Helena Allegretti, Secretary for Amazonia, Ministry of the Environment, public statement 1999).

Fig. 1.

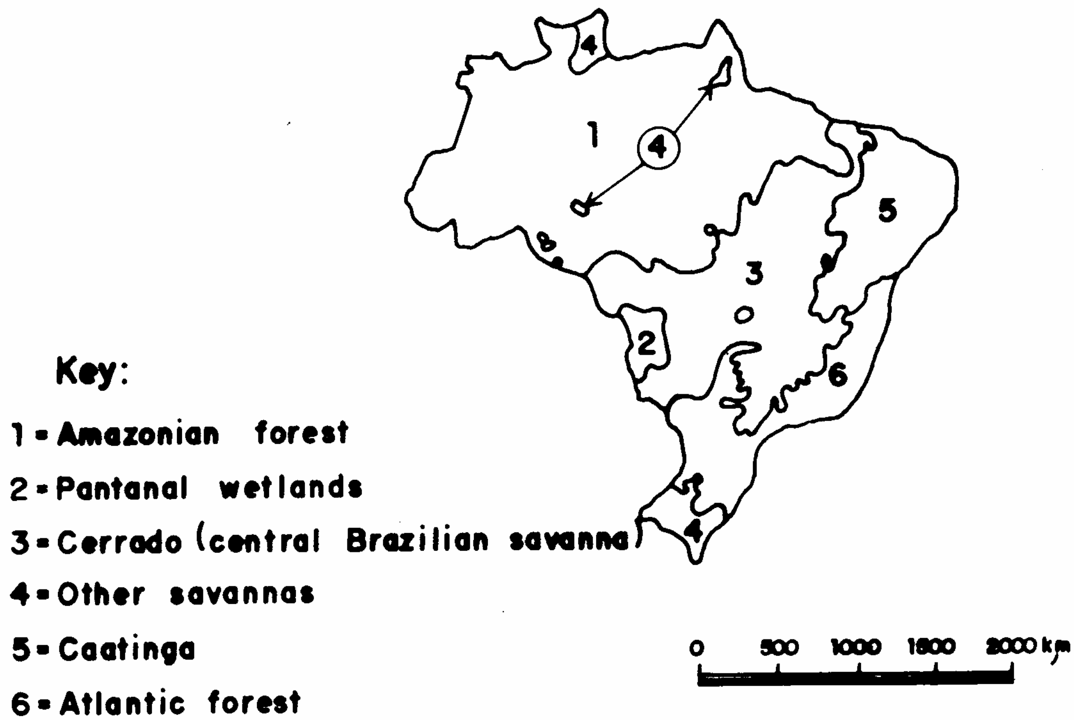

4
1
4
5
3
2
6
4
Key:
1 = Amazonian forest
2 = Pantanal wetlands
3 = Cerrado (central Brazilian savanna)
4 = Other savannas
5 = Caatinga
6 = Atlantic forest
0 500 1000 1500 2000 km

Fig. 2.

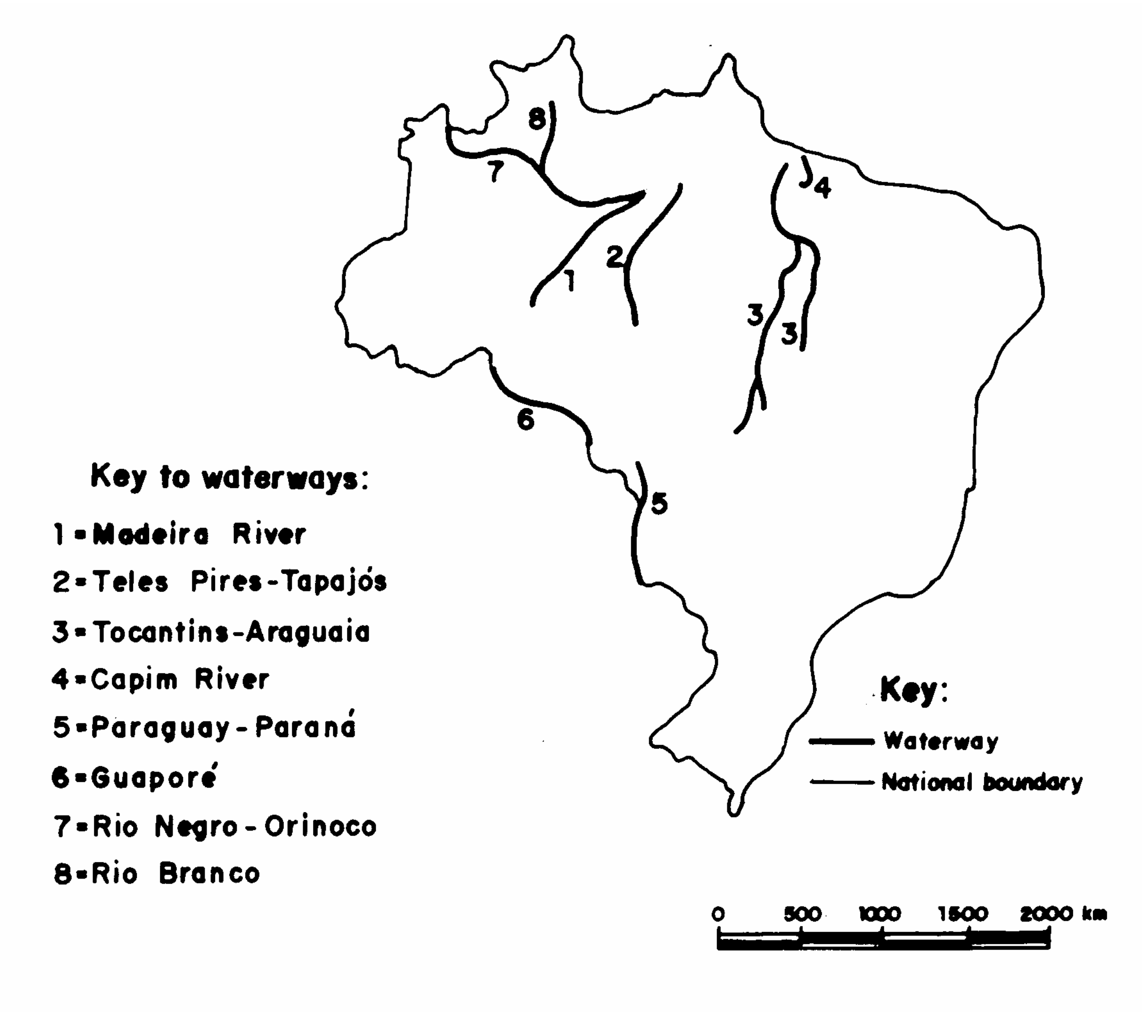

8
7
1
2
4
3
3
6
5
Key to waterways:
1=Madeira River
2=Teles Pires-Tapajós
3=Tocantins-Araguaia
4=Capim River
5=Paraguay-Paraná
6=Guaporé
7=Rio Negro-Orinoco
8=Rio Branco
Key:
Waterway
National boundary
0 500 1000 1500 2000 km

Fig. 3.

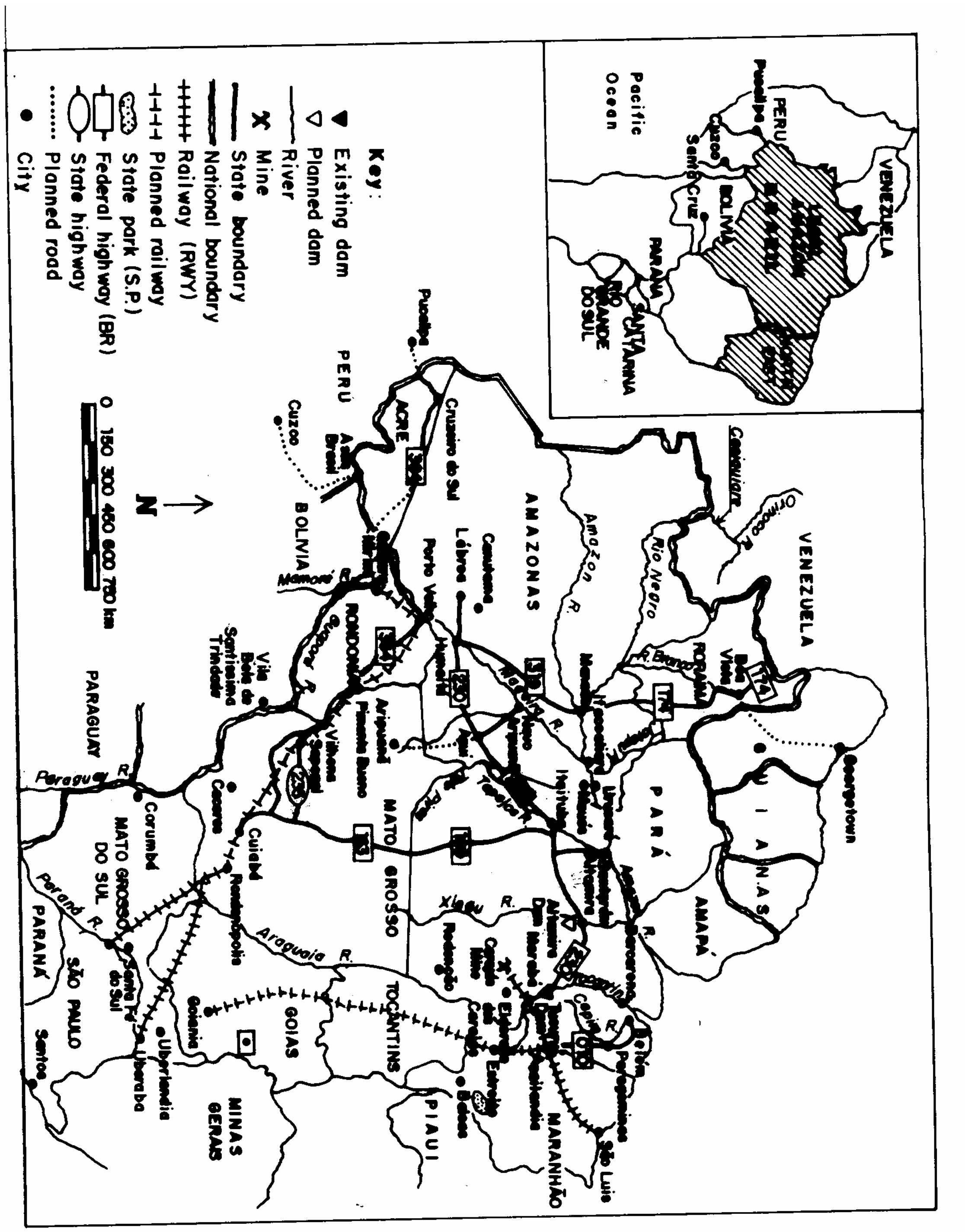

Key:
Existing dam
Planned dam
River
Mine
State boundary
National boundary
Railway (RWY)
Planned railway
State park (S.P.)
Federal highway (BR)
State highway
Planned road
City
0 150 300 450 600 750 km
N
VENEZUELA
AMAZONAS
PARÁ
AMAPÁ
MATO GROSSO
MATO GROSSO DO SUL
RONDONIA
ACRE
GOIAS
TOCANTINS
MARANHÃO
PIAUI
MINAS GERAIS
SÃO PAULO
PARANÁ
PERU
BOLIVIA
PARAGUAY
Pacific Ocean

Fig. 4.

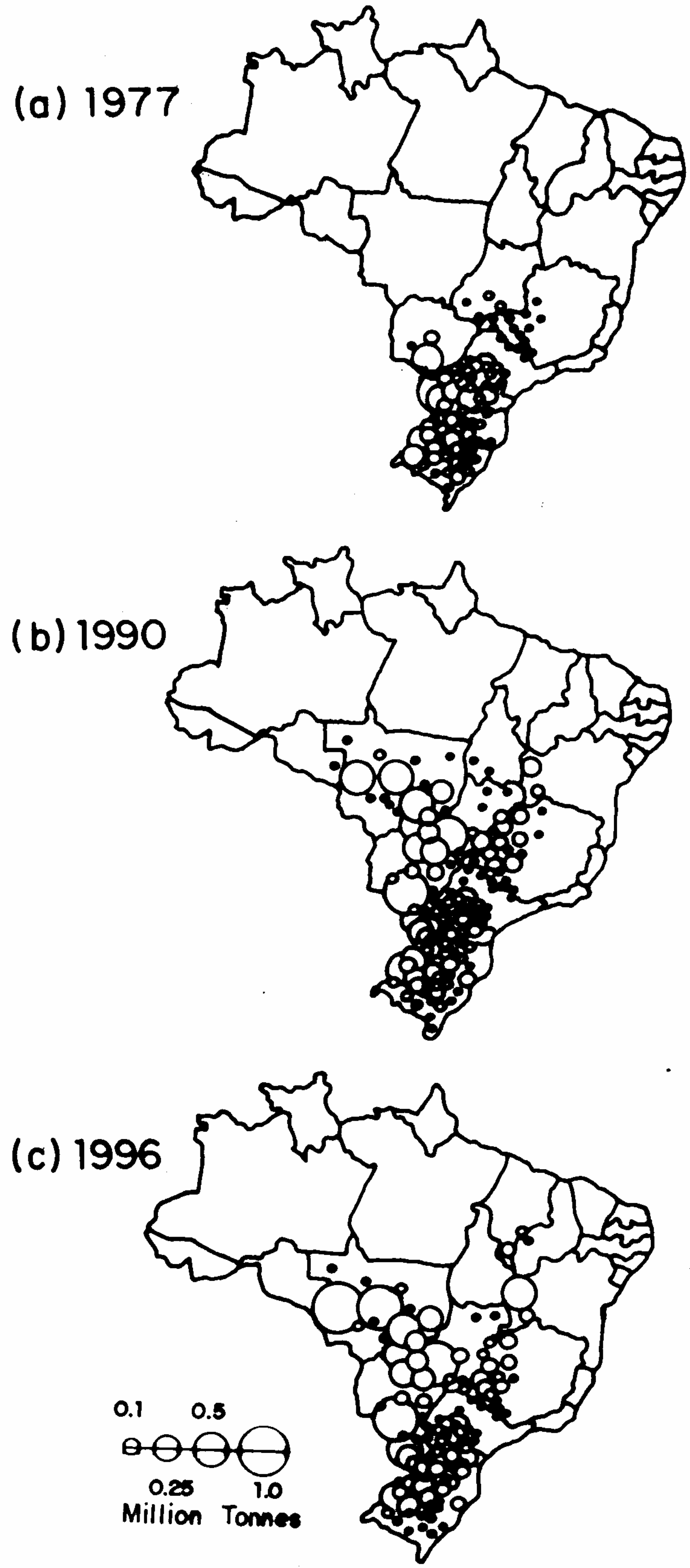
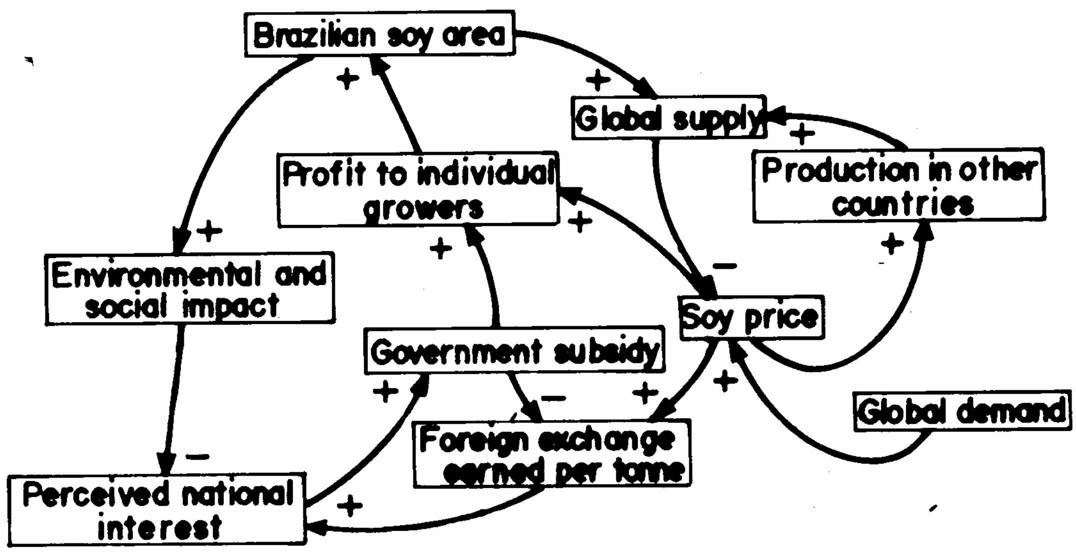

(a) 1977
(b) 1990
(c) 1996
0.1
0.5
0.25
1.0
Million Tonnes

Fig. 5.


Brazilian soy area
Global supply
Production in other countries
Profit to individual growers
Environmental and social impact
Soy price
Government subsidy
Global demand
Foreign exchange earned per tonne
Perceived national interest