5
Cerrado Agriculture and the Environment

Akio Hosono and Yutaka Hongo

Introduction

This chapter will discuss Cerrado agriculture from an ecological and environmental perspective and analyze the sustainable development of agriculture and livestock in the tropical savannah biome. The first section presents an overview of biodiversity and environmental conservation efforts based in the Cerrado, especially in the 20 years following the Rio Summit in 1992 ('Rio 92,' United Nations Conference on Environment and Development). Environmental conservation initiatives in the Japanese–Brazilian Cooperation Program for Cerrados Development (PRODECER) are then discussed in Section 5.2. It is worth noting that although this bilateral cooperation was conceived nearly 20 years prior to Rio 92, Brazil and Japan addressed environmental conservation as early as the first phase of PRODECER. In the following Section 5.3, the pattern of land use in the Cerrado is reviewed, drawing on Landsat satellite image information. From this analysis, it is estimated that 61 percent of the Cerrado remained as natural vegetation after more than two decades of intensive agricultural development.

It was in 2003, when over 20 years of PRODECER was coming to an end, that a transnational grain trade company (GTC), Cargill, constructed a soybean export terminal port and 60,000-ton storage silo in the city of Santarém, located midstream along the Amazon River. Section 5.4 of this chapter analyzes how the 'Soy Moratorium' – together with concerted efforts by the major stakeholders – limited the destruction of tropical rainforest in the Amazon. Section 5.5 discusses new Japanese–Brazilian cooperation efforts to conserve the environment, in both the Cerrado and the Amazon, including the Advanced Land Observing Satellite (ALOS) Image Utilization Project, which has been hugely effective in combatting illegal

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logging. Section 5.6 concludes the chapter, focusing on possible future challenges related to sustainable agricultural development in the Cerrado.

5.1 Biodiversity and environmental conservation efforts in the Cerrado

According to the Brazilian Ministry of the Environment (Ministerio do Meio Ambiente, MMA), the Cerrado biome is regarded as the second most biologically diverse region of Brazil, after the Amazon tropical rainforest biome. In terms of flora, the region is home to some 12,356 native plant species (roughly 44 percent of which are endemic to the Cerrado region), and its fauna includes 320,000 species (90,000 of which are insects). In particular, the transitional zones between the Cerrado biome and the adjacent Amazon tropical rainforest biome, and between the Cerrado biome and the Caatinga biome (a semi-arid zone in the northeast), have a wide variety of valuable endemic species. The Cerrado has become known as the savanna zone with the world's richest biodiversity (Ministerio do Meio Ambiente, 2010).

Plants in the Cerrado cope with the unique stresses of extreme nutrient shortages, high soil acidity, and high aluminum saturation, and are believed to have evolved to protect themselves against damage from ants and wildfires, making them a valuable genetic resource. In 1998, the NPO Conservation International, based Arlington, Virginia, designated the Cerrado region as a biodiversity hotspot.[1] The organization pointed out that original vegetation in the Cerrado region had decreased and become segmented due to agricultural development, and that the biodiversity of the region may be under threat.

In addition, the Cerrado region extends over Brazil's central highland plateau (*Planalto central*). This is an important location crossed by Brazil's three major rivers: the Amazon, Paraná (La Plata tributary), and the São Francisco (upper catchment area), which traverses the semi-arid region longitudinally from north to south and is the longest river in northeastern Brazil. Brazil's Forest Law (enacted in 1965) designated the portion of owned land for environment conservation, but that portion differs depending on the vegetation (biome). The percentage of the Cerrado region to be kept as 'legal reserve' is 20 percent.[2]

In the 1980s, worldwide concern over global warming and environmental conservation gradually mounted, almost in tandem with the development of Cerrado agriculture. In 1981, Brazil enacted its own basic environment law in the form of the National Environmental Policy Act; the spirit of this law was also incorporated into Brazil's new constitution

during the shift to civilian rule in 1988. In 1989, the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA) was founded to enforce Brazil's environmental policies.

Then, in 1992, Brazil hosted the world's first United Nations Conference on Environment and Development (UNCED), commonly known as Rio 92, since it was held in Rio de Janeiro, and was an active participant in the proceedings. In June 2012, the conference was again held in Rio de Janeiro (called 'Rio+20') to mark the 20th anniversary of the UNCED. A significant focus of the conference was the results of initiatives regarding environmental conservation and development implemented around the world over the past 20 years.

During this 20-year period, Brazil conducted a series of broad and varied initiatives aimed at environmental conservation. In the Cerrado region, the government especially pursued a balance between Cerrado agricultural development policies and environmental conservation policies.

In 1998, Brazil enacted the Environmental Crimes Law; and in 2000 the Forest Code was amended to enforce more strictly legal reserve percentages on landowners, and to enable the trading of reserve land with the land of other forested land owners. Also in 2000, the National System of Nature Conservation Units (SNUC) was established. This system was designed to organize categories for native reserves and to protect and restore the biodiversity found in their ecosystems.

From 2002 onwards, the Brazilian government further strengthened its efforts to protect the environment and Brazil's ecosystems. The establishment of preservation districts (described below), the Environmental Conservation Expansion Program, and the Action Plan for Prevention and Control of Deforestation were particularly important aspects of these efforts.

At the beginning of this period, in March 2002, the National Environmental Council (Conselho Nacional do Meio Ambiente, CONAMA)-303 environmental resolution designated water resource recharging areas, sloping areas susceptible to soil erosion, valley and floodplain forest areas, and the like as Permanent Protection Areas (APPs), even when they were within privately owned land. In addition, human disturbance of original vegetation was banned.

In 2009, the National Policy on Climate Change was established (Law No. 12187). This required the formulation of Action Plans for the Prevention and Control of Deforestation on a biome basis. In September of the following year, the Action Plan for Prevention and Control of Deforestation and Wildfires in the Cerrado (hereafter, PP Cerrado) was announced.

Table 5.1 Protected areas in the Cerrado (by unit and regulatory body)

Protection Unit	Federal protection area			State protection area			Federal and State protection area		
	Number	Area (km^2)	%	Number	Area (km^2)	%	Number	Area (km^2)	%
Strictly protected areas	22	41,166	2.02	86	16,943	0.84	108	58,11	2.85
Ecological station	5	10,927	0.54	23	528	0.03	28	11,455	0.56
National Monument	0	0	0.00	4	296	0.01	4	296	0.01
National park	15	28,925	1.42	50	14,820	0.73	65	43,745	2.15
Forest ecosystem reserve	1	1,280	0.06	3	1,188	0.06	4	2,469	0.12
Ecosystem reserve	1	34	0.00	6	111	0.01	7	146	0.01
Sustainable use areas	145	18,731	0.91	143	90,935	4.47	288	109,666	5.38
National forest	6	290	0.01	12	358	0.02	18	648	0.03
Reserve prohibited extraction	6	894	0.04	0	0	0.00	6	894	0.04
Sustainable development reserve	0	0	0.00	1	588	0.03	1	588	0.03
Animal protection reserve	0	0	0.00	0	0	0.00	0	0	0.00
Special wildlife zone	4	35	0.00	13	45	0.00	17	80	0.00
National property in private property	118	1,048	0.05	67	818	0.04	185	1,866	0.09
Environmental protection area	11	16,464	0.81	50	89,126	4.38	61	105,590	5.19
Total	167	59,897	2.93%	229	107,878	5.31%	396	167,777	8.13%

Source: Authors, based on MMA (2010).

In PP Cerrado, the factors quoted as causes of the loss of original vegetation in the Cerrado included the following: (a) the area set off as nature reserves was an extremely small portion of the overall Cerrado area; (b) illegal logging for the purpose of charcoal[3] manufacturing had increased; (c) existing logging areas had not been used as agricultural land; (d) extensive livestock production had taken place in reserves and preservation districts; and (e) surveillance systems were undeveloped. As targets to be achieved by the year 2020, the plan set a decrease of at least 40 percent in the annual deforestation area, the widespread adoption of tree-planting programs, and the construction of illegal logging surveillance systems. Particularly with regard to surveillance systems, there are incentives to apply the surveillance systems for use in the Cerrado since they are already adopted in the Amazon.[4]

The Environmental Conservation Expansion Program, which is meant to effectively manage extensive areas of privately owned land using satellite imaging technology, was launched through Presidential Directive 7029 at the end of 2009, at which time the government also introduced the Rural Environmental Registry (CAR, Cadastro Ambiental Rural).[5] In addition to making registered farmers eligible for institutional financing, this granted incentives such as vegetation restoration support without the immediate application of criminal penalties, even when vegetation had been altered within the protected area. In October 2012, the Ministry of Environment issued a decree which established the obligation of registering all agricultural land in Brazil in CAR within a year (or two years, if authorized by the President).

As of July 2013, 25 states and federal districts (DF) had agreed to participate with CAR. The National System of CAR (SiCAR, Sistema National de Cadastro Ambiental Rural) was established by Presidential Directive 7830 in October 2012. Moreover, Brazil's environment conservation policy was further strengthened by Law 12651 and Law 12727 (amendment to Law 12651), enforced in 2012, which included a new regulation regarding the width of riparian forests. Today, the latter two laws are known as 'the New Forest Code' (Novo Codigo Florestal).

Box 5.1 The New Forest Code and CAR

Brazil's agricultural production volume has skyrocketed since 2000. For example, total grain production doubled from 100 million tons in the 2000–2001 agricultural year to 204.5 million tons in the 2014/2015 agricultural year. This increase in agricultural production is largely due to, externally, strong demand from international markets and, domestically, an expansion in

farmland boundaries and improved productivity. At the same time, the expansion in the borders of agricultural land has meant an expansion in the agricultural frontier, which has led to a decrease in the original vegetation. Moreover, higher productivity has amplified concerns over environmental damage, such as the degradation of soil and water resources as a result of the use of fertilizers and pesticides. Brazil has designated the Amazon, the world's largest tropical rainforest, as a hotspot for diversity. On the other hand, the Cerrado region offers substantial potential for agricultural development, which has drawn the attention of various international environmental conservation groups with various motives.

The New Forest Code emerged from this political environment. This is a groundbreaking document that lays out the principles for agricultural development and environmental conservation in Brazil in 14 chapters and 83 articles, divided by theme, such as Permanent Protection Áreas (APPs, Areas de Preservação Permanente), Restricted Use Areas (Áreas de Uso Restrito), Legal Reserve (Reserva Legal), and CAR. The code is groundbreaking primarily because it mandates the recovery of original vegetation in areas that were deforested in the past and also stipulates in detail the extent to which the original vegetation must be restored in riparian forests (*mata ciliar*) by the scale of the river and the scale of the farmland.

The New Forest Code also designated CAR as the instrument that would ensure its effectiveness. Brazil has a massive land area; even if a law goes into effect, monitoring is rarely thorough enough and violators cannot always be detected. However, CAR, which uses cutting-edge technology, is expected to solve this problem. CAR aims to register approximately 5.2 million farms across Brazil (total land area of 329 million ha) so that environmental conservation can be monitored on all farmland.

The Minister of the Environment, Izabella Teixeira, has stated that the Code is a sign that Brazil's environmental conservation policy is starting a new chapter, and that Brazil has one of the strictest laws on forest conservation in the world. However, the Code has been criticized by agricultural proponents for an over-emphasis on environmental conservation and an inadequate agronomic basis – for example, in the standards for riparian forestation. At the same time, environmental conservation groups criticize it for its failure to prevent further expansion in farmland boundaries.

5.2 Japanese–Brazilian cooperation for Cerrado agriculture and Cerrado environmental conservation

Japanese–Brazilian cooperation in the Cerrado was first considered in the early 1970s, nearly 20 years in advance of Rio 92; the first document regarding coordinated agricultural development was signed in 1974. From the outset of the joint Cerrado Development Program (PROCEDER), both Brazil and Japan espoused the belief that "[a]mong the PRODECER principles, the concept that there is no sustainable

agriculture development without harmony with the environment is implicit" (Brazilian Ministry of Agriculture, Livestock and Supply and JICA, 2002, p. 36 of part 5).

As a consequence, environmental conservation measures were implemented from the outset of PRODECER. As well as strict adherence to the 20 percent reserve requirement in plantations, in order to prevent the reserve areas from becoming a haphazard patchwork of isolated areas, efforts were made to create concentrated areas where individual reserve lands were joined through a 'condominium' model, as well as to form micro-corridors of reserve land made up of individual reserves (both of which will be discussed later). Moreover, measures were promoted to preserve agricultural environments, such as the introduction of contour cropping, crop rotation, and no-till farming (direct planting).

From its early stages, Japanese–Brazilian technological cooperation for Cerrado agriculture (carried out by EMBRAPA and JICA),[6] pursued in tandem with PRODECER, also sought to emphasize environmental protection in agricultural development. Such initiatives began 15 years prior to Rio 92. Specifically, in PRODECER and Research Cooperation (1977–1992), efforts were made to minimize the impact on the environment and to establish sustainable and environmentally friendly agricultural technologies and processes that would preserve the Cerrado's natural resources.

From its earliest planning stages, CAMPO, which was responsible for implementing and coordinating PRODECER, paid proper attention to the environment. With respect to reserve areas, two forms of reserve were adopted: individual reserves and joint reserve areas. As a condominium strategy was adopted for the joint reserve areas in some of PRODECER sites, and individual reserves were lumped together in other sites, the natural vegetation was preserved in large units, which helped to protect species that required expansive habitats, thereby enabling the preservation of greater biodiversity. Furthermore, the individual reserves were usually located along water arteries that flow through the agricultural land. Dubbed 'micro-corridors,' these areas served to conserve water resources, maintain biodiversity, protect against soil erosion, preserve water quality, and allow local fauna to circulate freely. Along these water arteries, steep-sloped riverside forests and marshes were also reserved to protect areas rich in biodiversity. Current laws stipulate the width of forestation, based on the width of the river, required on both banks of a river in order to preserve natural vegetation (riparian forest, or *mata ciliar*). As such, PRODECER promoted environment and ecological preservation through condominium strategy and other initiatives related

to reserves. Current law reinforced this consideration with legal framework. PRODECER's initiatives in this regards are considered pioneering efforts.

In addition, in PRODECER sites, wide-ranging technical guidance and environmental enlightenment activities were provided to farm settlers by CAMPO and agricultural cooperatives. These tutorials covered a wide range of topics, including direct planting (non-tillage seeding), soil conservation through contour cropping, the prevention of soil degradation through crop rotation, the introduction of organic substances and microbial strains of *Bradyzhizobium spp*. (nodule bacteri selected by CPAC, and so on) as an alternative to nitrogen fertilizers, the introduction of biological control technologies to deal with disease and insect control, and tree-planting along rivers, in small green areas, and deforested land.

Environmental protection measures also included the establishment of windbreak forests to prevent the loss of topsoil due to wind erosion, banning the use of combinations of pesticides, taking care when diluting pesticides to avoid the pollution of water flows, and promoting adherence to environmental conservation by training laborers employed in farming. Through these efforts, the PRODECER projects, together with cooperative research, have striven to introduce environmentally friendly agricultural technologies, and to achieve sustainable agricultural production, while addressing such issues as environmental pollution.

Efforts aimed at Cerrado environmental conservation were further strengthened after Rio 92. Two new Japanese–Brazilian cooperation plans were initiated – namely, the Cerrado Agricultural Environmental Conservation Research Project (1994–1999) and the Cerrado Environmental Monitoring Survey (1992–2000).

In the Cerrado Environmental Monitoring Survey, conducted from 1992, JICA sent experts on long-term assignments to CAMPO, dispatched a survey team of experts on short-term assignments each year, and, over the course of eight years, conducted a survey of the impact of PRODECER sites in coordination with the Cerrado Agricultural Research Center (CPAC). Soil erosion, water quality and quantity, vegetation, and insects were chosen as monitoring indicators, and fixed-point observations were made for each. The results were published in 2000 in Yoshii et al. (2000), and the associated survey data and survey methods have become valuable resources in the pursuit of sustainable agricultural development.

At the same time, Japanese and Brazilian research cooperation at CPAC identified the establishment of sustainable agricultural technologies that

aim to strike a balance between agricultural production and environmental conservation as the main research focus. In 1994, the Cerrado Agricultural Environmental Conservation Research Project set four targets in technical cooperation, namely: (a) the assessment of agricultural and environmental resources using remote sensing technology; (b) improvements to soil degradation through the introduction of green manure and no-till farming; (c) integrated control of disease and insect damage (i.e., not solely through the use of pesticides); and (d) the introduction of sustainable cultivation technologies for soybeans (establishment of crop rotation systems). Each of these targets has been achieved.

Brazil's and Japan's efforts at environmental and ecological conservation have been successful; furthermore, PRODECER was never subject to criticism in terms of Cerrado environmental issues. In the future, these experiences with Cerrado agriculture will likely serve as valuable reference cases for both Brazil's and Japan's international cooperation efforts aimed at tropical sustainable agricultural development.

5.3 Land use of the Cerrado from an environment conservation perspective

Despite the increase of agricultural production in Cerrado in the last three to four decades, land used has not increased as fast as production. This is due to significant improvements in yield per hectare. According to the Brazilian Institute of Geography and Statistics (IBGE) farm census, 61.36 percent of the growth of agricultural production (soybeans, rice, edible beans, corn, cotton and coffee) in the Cerrado during the period between 1970 and 2006 was provided by yield growth, while the remaining 38.64 percent was due to an expansion of the planted area. The yield share of the total production growth varies depending on the period and the crops. The increases in yield were mainly achieved thanks to the technological development of EMBRAPA. *The Economist* emphasized this aspect in these terms: "the availability of farmland is in fact only a secondary reason for the extraordinary growth in Brazilian agriculture. If you want the primary reason in three words, they are EMBRAPA, EMBRAPA, EMBRAPA" (The Economist, 2010).

As a result of the development of Cerrado agriculture, the area used for crops amounted to 21,590,000 ha in 2002, occupying 10.5 percent of the total Cerrado biome, which is estimated at 204,700,000 ha, according to an analysis based on Landsat satellite images.[7] The same analysis showed that about 26 percent of the Cerrado, 54,150,000 ha, consisted of improved pasture (or cultivated pasture) in 2002. Hence, the sum of

cropland and improved pasture, which could be considered as total farm land for agriculture and livestock production, amounted to 75,740,000 ha, equivalent to 37 percent of the total of Cerrado. As there are urban areas in the Cerrado, which amount to 0.4 percent of the whole, and reforested areas corresponding to 1.5 percent, the total area with some kind of land use was equivalent to 39 percent of the Cerrado's total land. The other 61 percent had undergone no changes attributable to human activity, and were considered to be the natural Cerrado. Dr. Edyson Eiji Sano, head of the Remote Sensing Center of IBAMA, found it remarkable that 61 percent of the Cerrado was still covered by natural vegetation, as the 2002 land use map showed. He stated: "[t]here is no other region in the world with such intense food production preserving such a high level of natural vegetation" (see Chapter 8).

The spatial distribution of land use in the Cerrado is shown in Figure 5.1,[8] where light gray space represents natural vegetation. Black and dark gray spaces represent cropland and improved pasture, respectively.

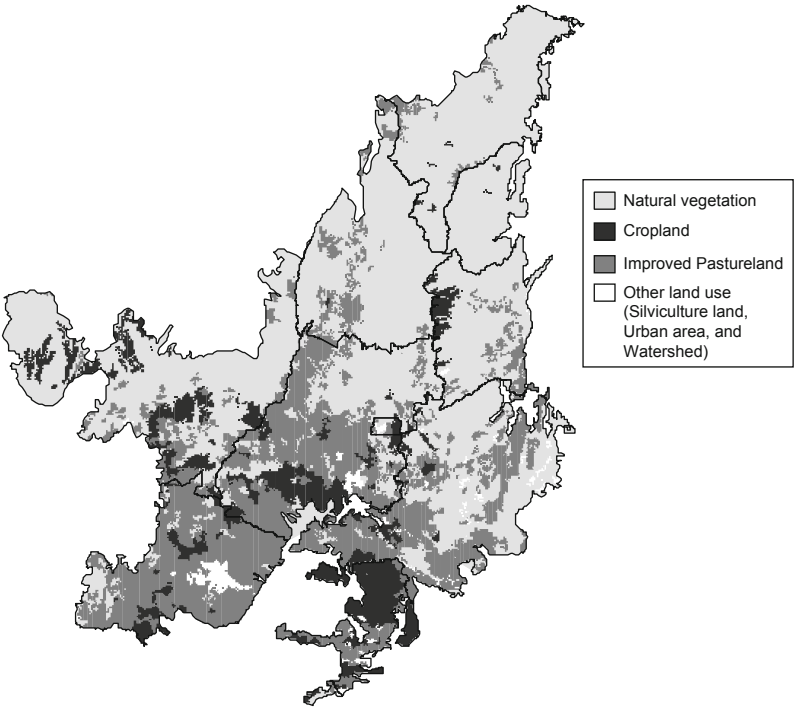

Figure 5.1 Spatial distribution of land uses in the Cerrado

It should be remembered that, in addition to the above-mentioned natural vegetation of the Cerrado, there are reserves equivalent to 20 percent of privately owned land.

Moreover, as discussed in Section 5.1, several new initiatives have recently been introduced to protect the ecology and environment of the Cerrado. Dr. Sano mentions that the deforestation of the Cerrado has shown a decrease since 2002. The area deforested each year was reduced from 15,701 km^2 (annual average) during the period of 1994–2002 to 14,179 km^2 in 2002–2008 (0.69 percent/year), 7,637 km^2 in 2008–2009 (0.37), and 6,469 km^2 for 2009–2010 (0.32) (see Chapter 8). The total deforested area as of 2010 was 48.5 percent of the Cerrado, according to the ministry of Environment.[9]

5.4 Impact of Cerrado agriculture on the Amazon rainforest

During the conception and implementation of Japanese–Brazilian cooperation aimed at the development of Cerrado agriculture, the possibility that Cerrado agriculture might have an adverse effect on the ecology or environment of the Amazon region was not the major concern. On the contrary, the expectation was that the expansion of agricultural development in the barren Cerrado region would act to contain negative impacts on the Amazon, and provide what could be called a cushioning or buffering effect. It was thought that agricultural production in Brazil would expand due to the development in the Cerrado region, which would then retard agricultural development in the neighboring Amazon rainforest, representing a benefit in terms of conservation of the Amazon biome.

However, the development of Cerrado agriculture began to have an adverse, albeit indirect, effect on the Amazon for the following two reasons. First, Cerrado agricultural products started to be shipped via the Amazon River, and roads from the Cerrado region through the Amazon became wider. Second, new tropical varieties developed for Cerrado agriculture also came to be used in the Amazon.

In April 2003, Cargill drew worldwide attention when it constructed its soybean export terminal port and 60,000-ton storage silo in Santarém, located midstream along the Amazon River.. The soybeans were directly loaded onto a dedicated Panamax-class crop-carrying vessel via a 360-meter conveyor belt from the riverside silo. From there, the crop carriers could travel directly to Asian countries via the Panama Canal. Before Cargill's construction of the soybean terminal, the Maggi Group had developed an export route using the Port of Itacoatiara, the first

to use the Amazon River. (See Chapter 3). However, this route greatly differed from that of Cargill. While Maggi's route passed through tributaries of the upper Amazon region from the Port of Porto Velho, Rondônia, onwards, Cargill's route, passed along a road constructed through the Amazon rainforest from the Cerrado region.

The Port of Santarém is situated at the northern end of National Route 163, and there were expectations that this road would be paved as a shipping route for Cerrado grain production. As shown in Figure 3.8, National Route 163 runs longitudinally from south to north, as if driving a wedge into the heart of the Amazon rainforest. Since there were also rumors that major crop producer Bunge would acquire land for an export base at the Port of Santarém in much the same way, there was concern that the paving of National Route 163 would go ahead and that the Amazon rainforest along the route would be destroyed. These concerns were supported by the fact that, to date, there have been strong indications of a correlation between the destruction of Amazon forests and road construction and improvement.[10]

There is a relationship between this situation and the use in the Amazon of a soybean variety developed for growth in tropical regions and widely used in the Cerrado. In Chapter 1, it was mentioned that one of the biggest factors in the success of Cerrado agricultural development was the cultivation of a tropical soybean variety. Soybean varieties less sensitive to photoperiod (the physiological reaction of organisms to the length of day or night) have been bred one after another, and coupled with improved soybean cultivation techniques; as a result, production volume in the Cerrado region has risen dramatically. At the same time, this innovation in tropical soybean varieties has meant that, technically, soybean could also be cultivated in the vast Amazon region right on the equator, where there is no variation in the length of the day or night. In fact, by the late 1990s, soybean cultivation had moved beyond the transitional vegetation zone between the Amazon and the Cerrado, and was being cultivated in the Amazon region. Soybean cultivation areas were first captured in official government statistics in 1997 for the state of Pará, and in 2001 for the state of Amazonas. This led to the Amazon rainforests being regarded as suitable locations for soybean cultivation.

Another concern was that the transnational grain majors (GTCs) would spend massive funds to stimulate soybean production in the Amazon region, which would have an overwhelming influence on global soybean production and distribution. The shipment of soybean from the Port of Santarém on the Amazon River was seen as the start of a large-scale, soybean-oriented agricultural development in the Amazon.

In these circumstances environmental protection groups, Amazon researchers, and the media collectively began to issue warnings. In September 2000, *Time* magazine published a special feature in which it asserted that the destruction of the Amazon environment was taking place due to three major factors: the development of roads, deforestation, and prescribed fires. In November of the same year, Brazil's largest weekly publication, *Veja*, also published a special feature. The magazine reported the shocking warning that by the year 2020, 42 percent of the Amazon rainforest could be destroyed, 95 percent of the total could be degraded, and only 4.9 percent of native forests could remain. Science and environmentally oriented overseas journals also ran a steady stream of articles containing similar warnings. In response to this press coverage, a boycott of Amazon soybeans was initiated in Europe, and placards along the lines of "Don't eat fast foods that devour the Amazon rainforests" (referring to broiler chicken raised on soybeans) were paraded in the streets. News of the European boycott of Amazon soybeans also received extensive media coverage inside Brazil.

Cargill's Amazon export base construction, which was taking place under these circumstances, did little more than add fuel to the fire, and resulted in heightened international concern. As a result, the ABCD group of grain majors active in Brazil,[11] the National Association of Grain Exporters (ANEC), the Brazilian Vegetable Oil Industries Association (ABIOVE), and major Brazilian companies such as the Maggi Group came to be labeled as the main culprits behind the widespread destruction of forests. Recognizing the risk of their products being boycotted by European markets, they struck a compromise with domestic and overseas NGOs[12] and explored ways to put the brakes on increasing soybean production in the Amazon's tropical rainforests.

On July 24, 2006, an agreement was reached on a groundbreaking private-sector-driven scheme known as the Soy Moratorium, whereby the parties agreed to directly inhibit "soybean production regarded as being on a forest destruction vector"[13], as a response to emergency circumstances.

The details of the moratorium comprise the following five points: (1) From July 24, 2006 onwards, companies under the jurisdiction of the National Association of Grain Exporters (ANEC) and the Brazilian Vegetable Oil Industries Association (ABIOVE) must not provide any production funds for, or make any purchases of, soybean produced on newly deforested lands or public lands (federal land, state land, reservations, etc.). (2) Whether or not soybeans have been grown on newly deforested lands is to be determined with the cooperation of the

National Institute for Space Research (INPE), using satellite images from Remote Sensing GlobalSat[14] and through visual confirmation made from the air and on the ground, and the results will be made public; the costs of this surveillance process are to be borne by ABIOVE. (3) The applicable regions are the states of MT, RO, and PA (Para), which account for 98 percent of soybean production in the Amazon region and where forest destruction had increased. (4) The Working Group will be made up of the ABCD group, ANEC, ABIOVE, major Brazilian soybean producers such as the Maggi Group, the Banco do Brasil (the government financial institution and the main source of agricultural loans), as well as domestic and overseas NGOs; the Working Group will receive all materials from GlobalSat and also take part in monitoring. (5) The initial duration of the Soy Moratorium was two years. The moratorium was effective, and has since been continuously extended. In October 2011, an agreement was reached to extend the moratorium until January 31, 2013. Later in November 2014, the moratorium was further extended to May 2016. In addition, in June 2008, when the Soy Moratorium was first up for renewal after its initial two years in effect, the Ministry of the Environment became a moratorium member.

Several technical problems have emerged with regard to the moratorium. The main issues have been: (a) the soybean cultivation season coincides with the rainy season, and the occurrence of cloud cover greatly hampers surveying; (b) the owners of designated fields are not identified; and (c) above-ground access becomes extremely poor during the rainy season. However, the public disclosure of GlobalSat reports and the fact that a national monitoring system was launched in response to widespread media coverage were major breakthroughs.

The expansion of the soybean cultivation area in the Amazon rainforest region was in fact suppressed: between the 2006 and 2011 seasons, the soybean cultivation area on newly deforested land was just 11,698 ha. It was also announced that this area represented no more than 0.39 percent of the total newly deforested area (roughly 3 million ha) in the three monitored states during the same period. Upon learning these results in October 2011, the Environment Minister declared that the soybean vector for Amazon forest destruction had been brought under control.[15] The Soy Moratorium Working Group made similar remarks. These achievements have been acknowledged by major Western consumers of Brazilian soybeans, such as Carrefour, McDonald's, and Wal-Mart.[16] The Soy Moratorium is regarded as an excellent example of improved governance of the Amazon region, made by the government, the private sector, and environmental protection NGO groups.

That said, even when areas are newly deforested, it takes a few years for the fields to support mechanized agriculture. Consequently, monitoring and regulation will also be required in the future.

Since the Soy Moratorium produced remarkable effects with regard to forests, in 2009 a similar schedule was applied to beef cattle being produced in the Amazon. After deforestation, land in the Amazon region is being used for extensively managed grazing pasture and there was considerable pressure from overseas importers and consumers for Amazon forest conservation. The numbers bear this out. Brazil is the world's largest exporter of beef, and had a herd of 208 million head of cattle in 2011. Over the previous ten years, this number increased by around 78 million. In contrast to other stagnating regions, the North region (which largely corresponds to the Amazônia Legal, or Legal Amazon region) has undergone significant growth. During the same period, the North region added 11 million head of cattle, and currently has a total of 37.9 million. Statistics on land usage (the area of regions where vegetation has been altered by human activity) in the Legal Amazon first released by Brazilian government agencies showed a cumulative 720,000 km^2 of land usage as of 2008, with 62 percent of this total area being used as grazing pasture; 21 percent is listed as degraded forest, and 4.9 percent is dry fields. The government has also acknowledged that cultivated pastures are the main factor in the destruction of the Amazon forests.[17]

In 2008, beef-related companies such as slaughterhouses, meatpackers, and the Brazilian Beef Exporters Association (ABIEC) reached an agreement that they would no longer purchase beef cattle or products processed from beef cattle produced on land newly deforested and converted into pasture, or on reservations in the Amazon region. Since grazing pasture accounts for the highest percentage of utilized farmland in the Amazon region,[18] this move was expected to play a large role in bringing forest destruction under control.

5.5 New cooperation between Japan and Brazil on environmental conservation

After PRODECER finished, a new Japanese–Brazilian project was launched with the aim of preserving ecosystems in the Amazon and Cerrado regions of Brazil. Initiatives included helping to protect the rainforest through the surveillance and prevention of illegal logging in the Amazon, as discussed previously, and protecting ecosystems in the Cerrado by reinforcing so-called ecological corridors.

Brazil is the only country in the world to have adopted a coherent surveillance system to protect its tropical forests. Since 1988, the Brazilian National Institute for Space Research (INPE) has published statistics showing the area of forestland destroyed each year, based on satellite images, and has continued to issue warnings regarding excessive deforestation. In 2004, the Plan of Action for the Prevention and Control of Deforestation in the Amazon (PPCDAM) and the Real Time Deforestation Detection System (DETER, Detecção de Desmatamentos em Tempo Real) were initiated, making it possible to monitor logging activity on a fortnightly basis. The federal police and the Brazilian Institute of Environment and Renewable Natural Resources (IBAMA), part of the Ministry of the Environment (MMA), began using satellite images provided by INPE to clamp down on illegal logging. There was, however, one major shortcoming in this surveillance system: the dense clouds that cover the Amazon during the rainy season were preventing the satellite's optical sensor from monitoring conditions on the ground. The breakthrough needed to resolve this issue came in the form of Japanese satellite technology.

In August 2006, JICA sent Dr. Manabu Kawaguchi, an expert in satellite image analysis, to Brazil for a period of six months to help IBAMA and the federal police to improve their geographic information system to prevent environmental crime. Dr. Kawaguchi concluded that the issue could be resolved by using data from DAICHI, the Advanced Land Observing Satellite (ALOS) operated by the Japan Aerospace Exploration Agency (JAXA), and he started to put his theory into practice. Launched by JAXA in 2006, ALOS uses a Phased Array type L-Band Synthetic Aperture Rader (PALSAR) microwave sensor instead of an optical sensor. This enables it to get a clear picture of the ground even in cloudy or rainy conditions, or at night. Whereas illegal loggers had previously been cutting down trees for half the year, hiding under cover during the rainy season, their activities were now exposed year-round, day and night. (JAXA's ALOS system is the only system in the world capable of providing satellite imagery around the clock.) There may have been a degree of skepticism about Japanese technology in Brazil at the outset, but ALOS images have proved to be hugely effective in combating illegal logging.

JAXA began providing ALOS data to IBAMA and the federal police in 2007, and in 2009 JICA launched the ALOS Satellite Image Utilization Project, together with IBAMA and the federal police, in order to improve ALOS imagery analysis capabilities. By using the results of this project, Brazil has greatly improved its satellite observation capabilities and its

ability to crack down on illegal logging activities. As a result of ALOS technology and Brazilian efforts, the loss of Amazon rainforest area has decreased sharply.

According to a study carried out by Climate Policy Initiative (CPI),[19] the control of illegal logging by satellite monitoring in the Amazon reduced deforestation by more than 59,500 km^2 during the 2007–2011 period. Deforestation in the period was 41,500 km^2, which is 59 percent less than the level predicted before satellite surveillance (Electronic Edition of O Globo, dated September 5, 2013). The use of ALOS to help prevent illegal logging marks a significant achievment in Japan–Brazil cooperation effort. The MMA is now expediting the development of detailed satellite-based survey and surveillance systems similar to those used for the Amazon region for the Cerrado region, as well.[20] ALOS2, which boasts an analytical capacity, with PALSAR radar, ten times higher than the first ALOS, was launched by JAXA in May 2014.

The Cerrado Ecosystem Conservation Project, which began in 2003, was implemented through cooperation between JICA and IBAMA; it aimed to improve ecosystem-integrated management systems for the Paranã–Pirineus Cerrado Ecological Corridor, which extends over GO and the Federal District (Brasilia). Japan's experience in the management of national parks was crucial to the project.[21]

The Jalapão Region Ecological Corridor Project in TO, which was started in 2010 and is still ongoing, has also attracted attention. An ecological corridor refers to a continuous networked space that links wildlife habitats and enables the movement of biota. The Jalapão region is situated in a transitional zone of the Cerrado region that separates the neighboring Amazon and Caatinga (semi-arid) regions, and features rich biodiversity. The region is located in the MATOPIBA zone, which comprises the states of MA, TO, PI, and BA, and which is currently at the forefront of Cerrado development. The project aims to connect the nature reserves distributed across the four states into an ecological corridor. To achieve this, the project is aiming to strengthen the structure of the implementing agency, the Chico Mendes Institute for Biodiversity Conservation (ICMBio), which was established in 2007.

5.6 Towards sustainable agricultural development of the Cerrado: future challenges

Historically speaking, the development of uncultivated land was once thought to be the equivalent of economic growth. Cerrado development began in such a context, and today the Cerrado has transformed

itself into one of the world's leading food production regions. There are also hopes that the Cerrado will become a source of renewable energy crops, particularly sugarcane; furthermore, the results of research into the cultivation of macaw palm, oil palm, and jatropha, which are now being tested in the CPAC, are highly promising. Global demand for food will continue to rise, along with that for bio-fuels, and the Cerrado region looks set to provide solutions. Achieving expanded agricultural production while conserving the environment and ecosystems (that is, seeking sustainable agricultural development) will, however, become an increasingly pressing need.

The role of government in advancing this concept of sustainable development is significant. In particular, it will be essential for government to do the following: (a) develop the policies and systems essential for sustainable development, and the related enforcement structures; (b) enhance zoning-based regulations and systems to monitor illegal activity; (c) build a framework for cooperation between producers, local residents, companies in the supply chain, environmental protection groups, and the government; and (d) support a solid technology transfer system through the existing state technical assistance and rural extension network (public and private) in order to provide users with agricultural technologies recently developed by research, development, and innovation (RD&I) institutions. This section discusses these duties in the light of the experiences gained from Cerrado agricultural development.

As the implementation of transport and logistics systems makes steady progress, the improvement of National Route 163 will serve as an example when conducting road improvements essential for agricultural development and the distribution of agricultural produce. The state of MT (and particularly the state's central region), Brazil's largest soybean producer, is situated inland, and producers there face the high cost of transporting their products to ports. To soybean growers in the area, the paving of National Route 163 up to the city of Santarém is a long-held desire. If National Route 163 could be paved in its entirety, it is expected that the export volume out of Santarém would increase from the current 800,000 mt to 10 million mt, and the economic effects would be significant. However, both the Cardoso administration (1995–2002) and the subsequent Lula administration (2003–2010) argued that there was a strong correlation between road improvements and deforestation, and postponed work on the roads until various related schemes could be developed. In fact, not more than 50 km of road were paved during the Lula administration, while 900 km of road remained unpaved. This is

an example of the need for caution when implementing development projects that impact on environmental conservation.

The Cerrado region having been designated as a biodiversity hotspot, there will be a growing need to introduce traceability to assure the sustainability of the region. Sustainable land utilization that strikes a balance between development and environmental conservation must be quickly established having in mind the new perspective of Cerrado agriculture development. There are three important steps that need to be taken in order to achieve this: (a) to implement a land utilization plan that uses zoning to separate land suitable for agriculture from protection areas; (b) to pursue efforts to enhance illegal activity monitoring; and (c) to enforce laws using satellite surveillance technologies and other means.

The Soy Moratorium was groundbreaking. The parties currently involved are urging farms in the Amazon region to register with the Rural Environment Registry (CAR). CAR has been extended to the whole nation. By having the farmers themselves receive support from Geographical Information System (GIS) professionals, and register geographical information about the farmland they own, farmland owners can be identified from satellite data, making it easy to determine the presence of illegalities. This is not just a means by which farmers complying with the law can express a positive stance on environmental conservation – it also brings with it significant benefits, including access to low-interest financing for agricultural schemes. For this reason, the majority of farmers have already completed provisional registration and are awaiting final certification.

Box 5.2 Initiatives promoting environment-conscious agriculture at field level in the Cerrado region

According to the 2010 Municipal Agricultural Production (Produção agrícola municipal) survey, released by the IBGE in 2013, a survey of the agricultural product value of annual and perennial crops (total of 64 items) in the 5,490 districts nationwide found that 19 of the top 20 districts were located in the Cerrado region. This report provided evidence, if such were needed, of the extent to which agricultural development in the Cerrado region has enriched the local economy. Agricultural development generates employment and absorbs the working population from other regions where unemployment rate is high and also provides a rich source of tax revenue for the district administrative office. The district administration can then use this financial resource to conserve the natural environment.

The São Desidério district in the state of Bahia has the highest agricultural revenue in Brazil. This district is located in the MATOPIBA region, which has currently gone the furthest in promoting Cerrado agricultural development, and has a population of 30,000 people and agricultural production amounting to about US$900 million. This district's administrative office has set its own environmental conservation standards, and is known for practicing sustainable agricultural practices, such as mandating no-tilling farming and farm-visit monitoring of APPs.

The environmentally conscious agriculture practiced in the Lucas do Rio Verde district in the state of Mato Grosso, which was ranked No. 20 in this report, has attracted attention from around the world. This district has a population of 50,000 and agricultural production valued at around US$200 million, and was ranked eighth nationwide in the FIRJAN (Federação das Indústrias do Rio de Janeiro) Municipal Development Index. In the first (2006) National Environmental Awards, given for 'environmental conservation and sustainable development' every year by *Jornal do Brasil*, Brazil's most influential newspaper, the Lucas do Rio Verde district government won the award for best environmental practices in the District Environmental Administration category. This is a good example of the manner in which prosperity can strengthen environmental conservation at municipal government level.

Programs addressing environmentally conscious agriculture are also under way at farmer level. Since Cerrado agricultural development requires massive initial investment in land reclamation and farm infrastructure, farmers are very interested in sustainable, environmentally conscious agriculture. Agricultural research institutions, primarily EMBRAPA, undertake the technology development in this area. The technologies currently receiving the most attention are non-tillage cultivation, crop/cattle husbandry/forest integration systems, and plant protection using natural enemies, as explained in Chapters 7 and 8.

In addition, programs that foster the development and dissemination of technology that supports environmental conservation are moving ahead among small-scale farmers and at the community level. EMBRAPA's publication *Sustainable management of agri-biodiversity in the Cerrado biome and Caatinga biome with emphasis on rural communities* (2011), gives many examples, and efforts are under way to encourage their spread.

All this is not to say that the environmental problems of Cerrado agriculture have been entirely solved. Currently (2014), the most pressing issue is the explosive proliferation of the larva of the *Helicoverpa armigera* insect, a moth that feeds on crops. The continuous cropping of a broad agricultural area encourages the infestation of this moth, and there are now concerns not only about the agricultural damage it may cause, but also about the contamination of water resources due to the heavy use of insecticides. The reality is that, despite a rush to breed insects that are this moth's natural enemy, such efforts were not made in time. Learning process driven by administrative guidance backed by abundant financial resources and farmers' own efforts will continue to be essential to establish environmentally conscious agriculture in the Cerrado region.

The environmentally conscious conservation practices and agricultural technology developed in Brazil after many tribulations can offer many lessons that could be useful for other tropical countries, including countries in Africa.

Notes

1. A region facing destruction despite boasting rich biodiversity. The Cerrado is one of 34 such locations around the world designated by the NPO Conservation International as a biodiversity hotspot.
2. Nevertheless, 35 percent is required in the case of the Cerrado biome located in the area of the Amazon tropical rain forest (Legal Amazon Area), as stipulated by the amendment of the Forestry Law enacted in June 2012.
3. There is a high demand for charcoal from Cerrado shrub forests, as it is required by the steel industry in the production of steel, making it highly profitable.
4. Remarks made by Environment Minister Izabella Teixeira on September 13, 2011 (from the news section of the Ministry of the Environment website).
5. A registry that uses a GIS to determine the borders of each farm, as well as the legal reserve and preservation areas in each part of owned land. Upon the request of a farm, expert contractors prepare digitized drawings of the land usage status inside each farm area. Electronic data are incorporated into Integrated Environmental Monitoring and Licensing databases operated by state government environmental agencies.
6. For details of this cooperation, see Chapters 1 and 6 of this book.
7. This is the result of research to map land use in the Cerrado at a scale of 1:250,000 using the methodology of Landsat image segmentation. The published research was supported by the Project of Conservation and Sustainable Utilization of Brazilian Biological Diversity of the Ministry of the Environment, World Bank Global Environment Facility and IBGE, among others (Sano et al., 2008).
8. As the definition of *Cerrado* differs among institutions such as the CPAC and IBGE, the figures above are not strictly comparable. For details, see Chapter 8.
9. This is cited from "A proteção do Cerrado", an article of *O Estado de sao Paulo*, (September 19, 2011) based on information provided by Ministry of Environment. See also Ministry of Environment (2014a).
10. When roads are upgraded, side roads are built at perpendicular angles on both sides of the main road, and deforestation is exacerbated. The tracks of these side roads are known as 'fish bones', as their pattern when viewed from above evokes this image. These fish bone structures can be easily found by searching the Amazon region using Google Earth. Three-quarters of the destruction of Amazon forest is said to have occurred in swaths of 50 km on either side of major roads.
11. An abbreviation referring to four transnational GTCs doing business in Brazil: ADM, Bunge, Cargill, and Dreyfus (Luis Dreyfus).
12. Greenpeace, The Nature Conservancy, the WWF, IPAM (Environmental Research Institute of the Amazon, a Brazilian NGO), and so on.
13. A term originally used to refer to vectors of insects carrying pathogens.
14. Known as GlobalSat from August 2007 to October 2009. The company name was changed to Geoambiente thereafter.
15. Electronic edition of *Valor Econômico* dated October 13, 2011.
16. These companies formed a group called the Amazon Alliance and take group-level action.
17. September 2011, Environment Minister Izabella Teixeira and Brazil Science and Technology Minister Mercadante.
18. EMBRAPA-INPE (2011).

19. The CPI is an NGO financed by Open Society Foundations, supported by George Solos. In Brazil, the Foundations' partner is the Catholic University of Rio de Janeiro.
20. Remarks by Environment Minister Izabella Teixeira on September 13, 2011 (from the news section of the Ministry of the Environment website).
21. JICA has made available on the Web video-based educational materials about the project to improve rainforest monitoring capabilities using ALOS. Visit http://jica-net.jica.go.jp/dspace/handle/10410/792 to view "Protecting the world's rainforests from space – coordination and cooperation between Japan and Brazil" (2011, 30 minutes).

Bibliography

Altmann, Nilvo (2010) *Plantio direto no Cerrado – 25 anos acreditando no sistema*.

Barona, Elizabeth, Navin Ramankutty, Glenn Hyman, and Oliver T. Coomes (2010) 'The role of pasture and soybean in deforestation of the Brazilian Amazon.' *Environmental Research Letters* [online], 5, 024002.

IBGE (Brazilian Institute of Geography and Statistics) (2010a) 'Indicadores de Desenvolvimento Sustentável Brasil 2010' in *Informação Geográfica*, 7 (Rio de Janeiro: Estudos e Pesquisas).

IBGE (Brazilian Institute of Geography and Statistics) (2010b) *Atlas Nacional do Brasil: Milton Santos*.

IBGE (Brazilian Institute of Geography and Statistics) (2010c) *Produção Agrícola Municipal: Culturas Temporás e Permanentes 2010*, Vol. 37 (Rio de Janeiro).

Chiaretti, Daniela (2013) 'Fiscalização por satélite diminui em 59% o desmatamento na Amazônia.' *Valor Econômico*, May 8.

EMBRAPA-INPE (2011) 'Dados municipais do levantamento de informações de uso e cobertura da terra na Amazônia: TerraClass 2008,' http://www.inpe.br/cra/projetos_pesquisas/tabela_municipios.pdf, date accessed May 30, 2014.

GlobalSat (2009) 'Relatório: Segundo ano de mapeamento e monitoramento da soja no bioma Amazônia,' http://www.abiove.com.br/sustent/relatorio08/moratoria_carderno_2monitora_0409.pdf, date accessed May 30, 2014.

GlobalSat (2010) 'Soy Moratorium,' http://www.abiove.org.br/site/index.php?page=soy-moratorium&area=MTEtMy0x, date accessed May 30, 2014.

Góis Aquino, Fabiana de and Maria Cristina de Oliveira (2006) *Reserva legal no bioma cerrado: uso e preservação* (Planaltina: EMBRAPA Cerrados).

Grupo de Trabalho da Soja (2013) 'Moratória de Soja: Mapeamento e monitoramento do plantio de soja no bioma Amazônia – 6°Ano,' http://www.abiove.org.br/site/_FILES/Portugues/03022014–160810-port_final_baixa.pdf, date accessed May 30, 2014.

JICA (2006) *Relatório de avaliação final: projeto de conservação de ecossistemas do cerrado: corredor ecológico do cerrado Paranã–Pirineus* (Brasilia: JICA Brazil).

Klink, Carlos A. and Ricardo B. Machado (2005) 'A conservação do Cerrado brasileiro.' *Megadiversidade*, 1(1), pp. 147–156.

Machado, Altair Toledo, Luciano Lourenço Nass, and Cynthia Torres de Toledo Machado (2011) *Manejo sustentável da agrobiodiversidade nos biomas Cerrado e Caatinga com ênfase em comunidades rurais* (Planaltina: EMBRAPA Cerrados).

Marchetti, Delmar and Antonio Dantas Machado (eds) (1979) *Cerrado: uso e manejo: V Simpósio sobre o Cerrado: EMBRAPA-CPAC, CNPq*. (Brasilia Editerra).

Margulis, Sergio (2004) 'Causes of deforestation of the Brazilian Amazon,' World Bank, Working Paper No. 22.
Martinelli, Luiz, Rosamond Naylor, Peter M. Vitousek, and Paulo Moutinho (2010) 'Agriculture in Brazil: impacts, costs, and opportunities for a sustainable future.' *Current Opinion in Environmental Sustainability*, 2(5/6), pp. 431–438.
Martius, C.F.V. (1951) 'A fisionomia do reino vegetal no Brasil.' *Boletim Geografico*, 8(95), pp. 1294–1311.
Ministry of Agriculture, Livestock and Supply (MAPA) and JICA (2002) *Japan-Brazil Agricultural Development Cooperation Programs in the Cerrado Region of Brazil: Joint Evaluation Study: General Report* (Brasilia and Tokyo: MAPA and JICA).
MMA (Ministry of the Environment) (2002) *Avaliação e identificação de áreas e ações prioritárias para a conservação, utilização sustentável e repartição dos benefícios da biodiversidade nos biomas brasileiros* (Brasília: MMA/SBF).
MMA (Ministry of the Environment) (2006) 'Programa nacional de conservacao e uso sustentavel do bioma Cerrado: Programa cerrado sustentavel,' http://www.mma.gov.br/estruturas/sbf/_arquivos/programa_bioma_cerrado.pdf, date accessed May 30, 2014.
MMA (Ministry of the Environment) (2010) *Plano de açao para prevenção e controle do dess0matamento e das queimadas* (Brasília: MMA).
MMA (Ministry of the Environment) (2014a) PPCerrado: Plano de Ação para Prevenção e Control do Desmatamento e das Queimadas no Cerrado, 2a FASE (2014–2015).
MMA (Ministry of the Environment) (2014b) Cadastro Ambiental Rural (website), http://www.car.gov.br/, date accessed May 30, 2014.
National Institute for Space Research (INPE) (2014) Projeto PRODES (website), http://www.obt.inpe.br/prodes/prodes_1988_2013.htm, date accessed May 30, 2014.
Nishizawa, Toshie and Hongo Yutaka (2005) *Amazon – Hozen to Seitai* [Amazon – Conservation and Ecology] (Asakura-Shoten).
Oliveira, Paulo S. and Robert J. Marquis (2002) *The Cerrados of Brazil: Ecology and natural history of a neotropical savanna* (Columbia University Press).
Presidência da República do Brasil (2012), National Congress, Law No. 12.651, http://www.planalto.gov.br/ccivil_03/_ato2011–2014/2012/lei/l12651.htm, date accessed May 30, 2014.
Ramalho, Paulo Ernani Carvalho (2008) 'Cerrado: Ecologia e Flora,' Vol. 1 (Empresa Brasileira de Pesquisa Agropecuaria-EMBRAPA/Cerrado).
Sano, Edson Eyji, Riberto Rosa, Jorge Luís Silva Brito, and Laerte Guimarães Ferreira (2008) 'Mapeamento semidetalhado do uso da terra do bioma cerrado.' *Pesquisa Agropecuária Brasileira*, 43(1), pp. 153–156.
Solbrig, O.T. and M.D. Young (eds) (1993) *The world's savannas: Economic driving forces, ecological constraints and policy options for sustainable land use* (Taylor & Francis).
Spehar, C.R., P.I.M Souza and FAO (1999) *Sustainable cropping systems in the Brazilian Cerrados* (FAO).
The Economist (2010) 'Brazilian agriculture: the miracle of Cerrado,' August 26.
Warming, Eugenius and Mário Guimarães Ferri (1973) *Lagoa Santa / a vegetação de Cerrados Brasileiros* (Itatiaia: Da Universidade de São Paulo).
Yoshii, Kazuhiro, A.J. Camargo, and Álvaro Luiz Orioli (2000) *Monitoramento ambiental nos projetos agrícolas do Prodecer* (Planaltina: EMBRAPA Cerrados).
Zakia, Maria José and Luis Fernando Guedes Pinto (2013) *Guia para aplicação da nova Lei Florestal em propriedades rurais* (Piracicaba: Instituto de Manejo e Certificação Florestal e Agrícola).