PROPERTY RIGHTS, TECHNOLOGY, AND LAND DEGRADATION: A CASE STUDY OF SANTO DOMINGO, CUBA

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This paper explores environmental-economic issues in the agricultural sector. It presents a case-study of the Municipality of Santo Domingo, in the province of Villa Clara. The goal of this paper is to explore the way in which property rights and technological packages promote and undermine the long-term ecological-economic viability of farming land in the area.

I chose this municipality on the basis of the sensitivity of plant ecosystems to environmental stress.[1] The paper examines two state farms, two cooperatives, and three family farms. These units are compared in terms of their efforts to prevent resource degradation problems and engage in conservationist activities. The experience of family farmers suggests that a reduction in the size of large farms in Cuban agriculture, and a recasting of their incentive structure and technologies away from those of large-scale state farms, can have a positive effect in terms of natural-resource conservation.

The productivity of state farms in the area declined in both the sugar and non sugar sector even before the Special Period (DPPF 1988:9; Martínez 1993). The degradation of natural resources, particularly soils and tree cover, helps to explain these declines in productivity and output. On the other hand family farms seemed to have been maintained or increased their productivity during the same period. No data was available to assess productivity trends for the agricultural cooperative sector.

Table 1 illustrates the output of state farms in Santo Domingo between 1983 and 1993, valued at current prices. The Manacas state farm (Empresa de Cultivos Varios Manacas, or ECV Manacas) reached its peak level of output for this period in 1985, with a value of production equal to 3,340,500 pesos. By 1990, its production had decreased to 2,227,600 pesos, a 33% reduction from its 1985 level. After the "Special Period" set in, agrochemical inputs became very scarce, and by 1993, the value of the state farm's output had fallen to 1,551,100 pesos, or less than half of its 1985 level. Table 2 shows the decline of output of the Manacas state farm by crop groups.

Most of the reduction in the farm's output occurred before the onset of the "Special Period." Moreover, according to the director of the Manacas state farm, due to the importance of this enterprise in producing vegetables for the region the Ministry of Agriculture (MINAGRI) tried hard to shield it from the fertilizer and pesticide scarcities associated with the "Special Period," by prioritizing the farm in the allocation of

1. This municipality was one of the three chosen by the Cuba team of the MacArthur Foudation funded comparative project "Rural Transformation in Socialist Societies." The Cuba team, to which I belonged, also chose the municipality of Güines in Havana province, and Majibacoa in the eastern province of Las Tunas. Whereas Güines represents an area with the best resource endowment, where agricultural development occurred early on, Majibacoa represents an area with a poor resource endowment and was a late comer to agricultural development. Santo Domingo represents "the middle of the road" in terms of the historical development of plantation agriculture in Cuba, and in terms of its natural resource endowment.

Table 1. Value of Agricultural Output Sold, in the Mixed Crop, Sugar, and Cattle Sectors (thousands of current pesos)

Items	Non Sugar	Meat and Dairy	Sugar	Sugar	Sugar
Empresa	ECV[a] Manacas	EP Cascajal	26 de Julio	Washington	C. Baliño
1983	1,992.9	6,794.1	—-	—-	—-
1984	1,992.9	6,794.1	—-	—-	—-
1985	3,340.5	6,449.2	3,626.4	15,783.1	7,214.0
1986	3,062.8	5,782.2	3,130.1	13,300.0	6,308.3
1987	2,091.0	5,367.1	3,045.6	9,844.4	4,005.1
1988	2,927.7	5,372.2	3,213.9	14,651.1	6,729.8
1989	2,626.1	5,164.2	2,923.8	12,185.6	5,019.4
1990	2,227.6	5,760.5	3,836.4	13,522.2	7,418.8
1991	2,378.4	3,973.0	3,284.5	12,633.4	5,342.4
1992	1,958.9	3,324.5	2,997.1	11,644.6	5,650.5
1993	1,551.1	2,409.9	1,070.3	10,041.8	5,038.6

Source: Informe de Economía Municipal, OME, Santo Domingo, (various years); and Tabla de Trabajo y Salario, OME, Santo Domingo, 1991, 1992, 1993. As reported by Rural Research Group of the University of La Habana.

a. Includes the ECV Cascajal, formed in 1991, which previously belonged to the ECV Manacas.

Table 2. Output of the Manacas State Farm by Crop Group, 1985-1991 (quintals)

Year	Viandas[a]	Vegetables	Citrus	Fruits[b]	Other	Total
1985	143,816	330,248	117,640	5,721	4,013	601,438
1986	111,971	296,663	92,888	12,709	6,089	520,320
1987	110,486	157,794	92,820	22,330	4,987	388,417
1988	90,193	244,206	98,973	16,571	3,642	453,585
1989	121,704	171,992	61,731	11,195	13,082	379,704
1990	73,905	164,057	78,359	23,619	16,694	356,634
1991	61,518	109,213	60,362	19,208	2,853	253,154

Source: Registro de Datos Históricos, Empresa Cultivos Varios Manacas, Santo Domingo. Reported by the Rural Research Group of the University of La Habana.

a. Tubers, roots and plantains
b. Non-citrus fruits.

these inputs (Yera 1993). However, as I show below, the MINAGRI did little to halt the degradation of the farm's soils. On the contrary, its production strategy intensified the use of natural resources, without setting up a program of natural-resource conservation.

A similar argument can be made in the case of sugar agro-industrial complexes (CAI). Santo Domingo's sugar production peaked in 1985 with a value of output equal to 26,621,500 pesos. Despite the national efforts to increase sugar production, prompted by Cuba's external debt crisis during the late 1980s, Santo Domingo's sugar output trended downward from 1985 on. And while output bounced back in 1988 and 1990, the downward trend prevailed. In 1989, the value of sugar output was 20,128,000 pesos, or 24% less than in 1985. By 1993 sugar production had decreased to 16,150,700 pesos, or 39% less than in 1985. The production of milk and meat also suffered from significant reductions before the onset of the "Special Period." The value of output of the EP Cascajal (producers of meat and dairy products) stood at 6,794,100 pesos in 1983. By 1989, it had fallen to 5,760,500, for a 15% decrease. By 1991, the value of milk and meat production had gone down to 3,973,000, or 41% less than in 1983. By 1993, it had collapsed to 2,409,900, or 65% less than in 1983.

Clearly, without subsidized Soviet inputs, Santo Domingo could not return to the pre-crisis levels of output. Notably, this was not the case in the small farmer sector. Table 3 presents data on the sales of this sector to the state, disaggregated by crop groups. According to several farmers interviewed and to the official data available, the output of private farmers in Santo Domingo increased between 1990 and 1993, despite the widespread scarcity in agrochemical inputs and fuel, and before the opening of produce markets in 1994. After an initial decline, the total value of sales from family farmers to the state grew from 71,473 pesos in 1990 to 101,443 pesos in 1993, for a 42% increase. While the opening of produce markets in 1994 would enhance private incentives to produce, output increases were recorded even before the opening of markets. An important question is, how can private farmers maintain and increase production in the face of widespread chemical-input scarcities? The answer given in this paper is that the small-scale production technologies used by small farmers as well as their private incentives make small farmers willing and able to invest in natural resource conservation.

STATE FARMS

Natural-resource conservation was not a goal of state enterprises, and while managers had a de jure duty to conserve natural resources, this was not enforced. For example, failing to fulfill the productive plan may have resulted in the dismissal of the enterprise's director, no such penalty existed for failing to conserve natural resources. The failure to structure similar incentives for resource conservation had negative consequences with respect to conservation decisions.

At the Manacas State Farm little importance was paid to even the most basic and inexpensive anti-erosive measures: plowing perpendicular to the slope, the construction of barriers at the margin of irrigation canals, and the use of cover crops (Yera 1993). To be sure, changes in the spatial distribution of different crops and reduced tillage had been used in different sectors of the enterprise. Since the "Special Period" began in 1990, the MINAGRI experimented with the use of alternative fertilizers such as organic matter, humus, and sugar cane ashes. Soil amendments were used only if they fostered short-run productivity. Yet since their short-run productivity increases are small, low tech, alternative practices were not sufficiently supported by state farms; they were often perceived as costly conservation measures that compete with "real" production activities.

Table 3. Santo Domingo's Private Farmer Sales to the State (quintals)

	1990	1991	1992	1993
Total	71,473	67,674	67,796	101,443
Tubers & Roots	5,562	2,732	15,073	31,234
Vegetables	44,951	40,369	31,251	58,131
Rice	76	775	506	35
Corn	746	1,658	1,404	1,252
Plantains	7	6,462	13,492	8,155
Citrus[a]	2,189	2,545	2,986	2,308
Fruits[b]	17,942	13,233	2,904	296
Beans	15	22	58	32
Milk[c]	n.a.	243.2	190.3	305.3
Pork (kg)	n.a.	2,271	n.a.	n.a.
Meat (kg)	n.a.	437	7,228	815

Source: As reported by Rural Research Group of the University of Havana

a. Citrus Fruits
b. Non-Citrus Fruits
c. Thousand liters

State farms were created to produce a specific product or set of products. The Manacas state enterprise was specifically created to produce vegetables, particularly tomatoes, because of the success of tomato production in the area before 1959. But this productive specialization was imposed from above in an inflexible way and served as an obstacle for conservation. In the case of the Manacas farm, tomato monocropping led to the persistence of nematodes in the soil, with a crippling effect on productivity. Crop rotation (with nitrogen-fixating varieties)and fallow periods were necessary, particularly in areas planted with tomatoes. Yet the state control over the output-mix and the technology used impeded the revamping of rotation patterns.

Given that the main responsibility of this enterprise was to produce tomatoes, enterprise managers always allocated the most fertile plots to that crop. The most modern irrigation systems were in place in these fields. Further, these fields were cultivated all year round.

The Manacas state enterprise was among the first in the province to engage in the intensive use of traditional irrigation in the early days of the revolution (ENPA 1986:9). Traditional irrigation systems waste much water, foster soil erosion and the silting of canals, and require much maintenance work. According to Yera (then director of the Manacas Enterprise), traditional irrigation has taken a heavy toll upon the enterprise's topsoil. Much runoff is generated by this water-intensive method, resulting in erosion and leaching. Given the subsoil conditions that prevail in the area, irrigation tends to worsen flooding problems.

MINAGRI officials at the provincial level, as well as enterprise administrators, identified deficiencies in irrigation as one of the main causes of the low productivity of inputs in the Manacas enterprise. In 1986, the MINAGRI set out to increase the areas under irrigation in the Manacas enterprise and to transform the outdated irrigation systems there. However, both of the systems promoted erosion and led to inflexible land use patterns which impeded environmentally-sound crop rotation schemes.

The Volshanka irrigation machines that were installed require that furrows follow the longest side of the field. But because of the design and distribution of fields in this enterprise, the longest side of the field often coincided with the direction of the slope. Therefore, the use of this irrigation technology increased the sensitivity of the agricultural system to erosion: by eliminating furrows that are perpendicular to the slope it increases the amount of runoff generated and its erosive force. On the other hand the DDA mechanized sprinklers made irrigation work very difficult and required that workers be trained to use them. Furthermore, routine irrigation activities may have created sizable erosion problems. Yet given the relatively low wages and the lack of well developed self-provisioning schemes, the labor force at the Manacas state enterprise was very unstable. Even the chiefs of irrigation frequently quit. Therefore, at any given time, many of the workers handling irrigation equipment had little training and experience. Thus, the workers managing irrigation technologies and water resources may actually contribute to erosion, waterlogging, and water waste.

Irrigation systems in the enterprise have generated an additional problem. The construction of irrigation canals and other infrastructure investments impose a rigid land use pattern. Those areas where irrigation systems are in place, which comprise 70% of the cultivated land, were used very intensely, often without fallow periods. Irrigation systems also limit the kinds of crops that the enterprise decided to plant in each area, and thus the choice set for crop rotation. Tomatoes were almost exclusively planted in areas where machine-based irrigation was in place. The fact that tomatoes were planted in the same (irrigated) fields led to the persistence of nematodes, a pest that severely reduced tomato yields.

Resource conservation could have been pursued by careful performance of the soil preparation tasks. However state control reduced the enterprises' space for decision making, and limited their ability to face environmental stress and shocks. Decisions came from the MINAGRI and often disregarded the conditions of the soil, climate, and the state of infrastructure-works. The provincial MINAGRI or MINAZ specified deadlines for planting and harvesting all fields. If the soil was too dry soil preparation led to eolic erosion; and if it was more humid than required, it resulted in soil compaction.

Due to the pressures put on workers to plant larger areas and to catch up with piled-up work, pre-planting soil preparation was sometimes carried out very quickly. Poor soil preparation had adverse consequences for soil fertility, humidity, and structure.

From the point of view of most of the decision makers of the Manacas state farm and the "26 de Julio" sugar complex, inadequate drainage was the main obstacle to increases in productivity. Several factors determine the occurrence of flooding, which affects much of the agricultural areas in Santo Domingo. First, the existence of a hard layer of clay (hard pan at a depth of 20 to 50 cms.) does not readily permit water to travel deep underground. Second, the water table is very close to the surface in many places. Third, while the original vegetation may serve as a sponge, absorbing water during rainy periods and releasing it during dry periods, the area is severely deforested. Fourth, drainage problems have been worsened by increases in irrigation, and by the hardening of the soil due to the use of heavy agricultural equipment (i.e. soil compaction).

Soil compaction is a pervasive problem in Cuba, and is caused by the use of heavy equipment. Their constant use hardens the soil, reducing its capacity to absorb water, which, in turn, contributes to waterlogging. The hardened soil reduces the plant's root growth. Deep subsoiling may solve the problem, but subsoiling equipment is not widely available. Furthermore, subsoiling requires large expenditures of scarce fuel.

The decision not to tackle the problem of flooding in Santo Domingo is based in part on the large amount of resources required by the "high-technology" model of farming and its lack of an ecological framework. The agricultural ministries classify the problems into seemingly unrelated compartments: according to Remo Pérez (1992), a soil technician with the MINAGRI in Villa Clara, "[i]n lowlands the important thing is flooding, in mountains, erosion. In Santo Domingo, instead of soil conservation we need to deal with drainage... "

The soil specialist classifies the soil as poor, focusing on one problem in the abstract (flooding) and dismissing other problems as minor in comparison. Solving "the main problem" in this case would require a large investment that the state cannot currently afford. As a consequence, provincial officials do nothing about flooding and erosion at the Manacas farm. Two changes in the mid-level bureaucrat's perception of land degradation, within the organic framework of an alternative farming model, could bring about a very different strategy to deal with the problem.

First, they need to understand that flooding, erosion, the persistence of pests, and other problems are all related to one another. Second, the poor quality of the soils is directly associated with erosion and leaching because both processes reduce the amount of organic matter and minerals in these soils. Moreover, the notion that flatlands are not prone to erosion is a myth. Sheet erosion is pervasive in this type of (sandy) soil (Febles and Durán 1988). Furthermore, a study conducted by researchers at the National Soil Institute of Cuba showed that this area is highly prone to leaching through the dissolution of mineral nutrients in the soil (González, et al. 1991).

To solve the problem of nutrient loss, chemical fertilization is supposed to be carried out according to tests performed by the Soils and Fertilizers office of the provincial MINAGRI, which schedules tests for different areas every year. However, fertility tests are few and far between, the number of plots tested is small, and their distribution is so irregular that no solid conclusions may be derived about fertility conditions (Fundora, O. 1993). The MINAGRI claims that testing is crucial for the allocation of scarce fertilizers but, ultimately, technicians made their decisions regarding the composition and quantity of fertilizers to be applied in each field without adequate data. Because of the sheer size of the enterprises and the scarcity of workers, state farming did not afford many alternatives.

Awareness is crucial for the design and enforcement of rules and technologies that may promote sustainability in resource use. Different perceptions of land degradation problems also seem to permeate the MINAZ in this area. Top administrators in the CAI "26 de Julio" do not recognize erosion to be a problem; they too believe flat soils are not erodible. However, some mid-level managers are aware of the erosion problem. About 50% of the arable land of the CAI "26 de Julio" consists of highly erodible sandy soil (the same type present in the Manacas state farm). Erosion is a problem in places where irrigation is used. Camilo Cárdenas, production chief of the second brigade, admitted that conservation has never been a priority; "I have tried to call attention to the erosion problem, but we have a small amount of time to plant and great pressure to harvest. Some things are accomplished; we have ploughed against the slope" (Cárdenas 1993). The vague soil-conservation directives issued by the MINAZ did not structure any incentives for compliance nor monitoring and enforcement mechanisms.

Cárdenas pointed out some of the limitations that made it difficult to carry out anti-erosive measures, even if information of the problem was adequate. First, Cárdenas confirmed the lack of concern about erosion and the perception, by planners and managers, that relatively flat-sloped soils are not erodible (Cárdenas 1993). Second, the farming technology used limited the institutional resilience of state farms to deal with land degradation. For example, large harvesting combines require long furrows (otherwise the combines would make many turns, thus complicating their maneuverability). However, just as in the Manacas enterprise, whether the longest side of the field coincides with the direction of the slope was not taken into consideration. If furrows are aimed towards the slope, irrigation or rain water moves with greater speed, thus increasing its erosive force. Conservation tillage, which lessens soil erosion and the loss of nutrients, is not an option because of the employment of heavy equipment. Third, he pointed out that most, if not all, of the tasks performed are aimed at increasing output; conservation was not a priority, but maximizing output was.

In sum, the evidence presented suggests that state farms did a poor job of protecting the environment in agriculture. The strategy of agricultural modernization at all costs, imposes a "high-technology" production paradigm which results in severe environmental degradation, and which demands "high-technology" solutions. For a while, short run productivity gains associated with agricultural modernization made up for the productivity losses associated with environmental degradation. This limited the environmental awareness of workers, managers and planners, who in addition have no incentives to seek information regarding degradation nor to pass it along. Neither workers nor managers and administrators have incentives to tackle resource degradation problems.

INDIVIDUAL FARMS

Private property rights and access to social services give small farmers the incentives to invest in conserving natural resources. Yet property rights and the safety net cannot explain why farmers choose specific production technologies that enhance their resource base. In this section I look at both incentives and technologies that help small farmers protect the environment.

Private farmers retained control over their land and productive process at the "expense" of their limited access to chemical and mechanical inputs and to economies of scale in production. Along with credit, equipment and extension services are made available through service cooperatives (the Cooperativas de Crédito y Servicios or CCS). During the first thirty years of the revolution, family farmers gained access to mechanical inputs such as small tractors, turbines, and to a low but consistent supply of chemical inputs such as fertilizers and pesticides.

Small farms belong to the families, one member of which, usually the male head of household or "independent peasant," controls most production decisions as well as the appropriation and distribution of the surplus. The land can only be sold to the state, or bequeathed to the peasant's children. This is an important rule because it virtually eliminates the incentive to produce by running down natural resources and then selling it for an alternative use. Small farmers can also transfer their land to a cooperative and become a member. These private property rights are curtailed by the state's control of various aspects of family production. The state controls small farmer's access to, and prices of, chemical and mechanical inputs, equipment, fuel and credit.

While private property rights, including access to stable marketing outlets, support the development of small farms, state limits on these rights curtail them. State officials dictate part of the output mix and its part of its distribution and suggest production techniques, and further limit the access to inputs and credit if the farmer does not comply. Failing to comply with the state productive plans can also result in fines.

Case Studies

Fernando García Cairo, a 65 year old peasant, farmed the land for thirty years at Paradero de Alvarez, Santo Domingo, and was a beneficiary of the first law of agrarian reform. His multicrop production takes place on 7.5 has. and includes peppers, tomatoes, beans, corn, cucumbers, and different kinds of squash.[2] Multicropping patterns reduce the farm's sensitivity (e.g. to pests) and increases its resiliency by maintaining fertility. Crop variety spreads his risk of crop failure. He has some fowl birds and two oxen, but has no cows or horses. His knowledge does not come exclusively from experience. Having learned to read during the literacy campaigns of the 1960s, he developed a passion for books about soils and farming (García Cairo, 1993). If available, he makes use of small amounts of chemical fertilizers and pesticides.

A four inch turbine pumps water from underground and is used to irrigate all of his land with small aspersors or with traditional methods. The soils on García's farm are sandy and hilly, making them extremely prone to erosion. Small farmers are well aware that irrigation on their land could wash away the soil. In order to minimize erosion, he divided the farm into blocs by digging small canals that follow the direction of the slope (perpendicular to the furrows) and created planting beds. Water is poured on the canal on the superior part of the planting bed. This system maximizes the land surface exposed to the irrigation water, possibly leading to greater erosion if irrigation is not performed carefully. But he irrigates slowly and carefully, which maximizes the absorption of water and minimizes runoff, and thus erosion.

García constantly rotates his crops, avoids planting crops that might allow pests to persist, uses nitrogen-fixating crops, as well as plants that serve as green-manure. His rotation and intercropping patterns are intimately associated with his fertilizer and pest-control needs. García has used urea and chicken manure as fertilizer since 1987, but he can only secure limited quantities (enough for 1 hectare a year). The application of chicken manure requires a very labor intensive process of soil preparation. Because of its strength, fields treated with chicken manure are left idle for about two years. According to García, fields treated with chicken manure do not need fertilizer for up to five years thereafter. Other small farmers also fertilize with *cachaza*, decomposed sugar cane, crop residues, and tree debris.

One such farmer who uses organic fertilizers is Francmacio Pérez Chavez. Francmacio lives on a farm he inherited from his father with his family. His brother's family, and his daughters, sons in law, and grandchildren live in a two-story house and two one-story houses at the edge of the small farm. His father was a beneficiary of the first law of agrarian reform; the land had been taken over in 1957 by one of the sugar companies in Santo Domingo and was subsequently expropriated and redistributed to his family, which numbers twenty people. Most family members help sporadically on the farm. He has a 1½ inch turbine, no tractor, three cows, two oxen, and one horse.

Pérez Chávez produces more than forty products on less than three hectares of land. His rotation sequence is based upon planting a nitrogen-fixating crop (e.g. beans) or one which leaves large amounts of residues (e.g. rice), before planting a demanding crop (e.g. corn). He uses both an alley distribution, with crops planted in between lines of trees, and a mosaic pattern, with fruit trees on one quadrant, animals on another, annual crops on another, and vegetables on yet another. A dirt road divides the farm into two halves with fences made of cacti.

Cropping patterns which combine lines of trees with vegetables and grain patches are found on many small farms, albeit with differences in crops and tree combinations. Some farmers emphasize fruit trees.

2. In 1992 García sold more than eight hundred quintals of tomato, chile, cucumber and squash to Acopio, the state procurement agency.

One of the farmers interviewed, Jacinto Pérez, specializes in fruits, some of which are very hard to find elsewhere. This farm started as a producer of mangos and oranges. However, after planting, farmers have to wait a minimum of eight years for the trees to mature and produce commercially. In the meantime, Jacinto's father, the original owner, experimented with grafting and sold plantlets of locally improved varieties of mangos, oranges, and avocados. In 1995 the selection included oranges,[3] mango, avocado, lemon, *mamoncillo*, tamarind, *marañón*, *red mamey*, *mamey Santo Domingo*, *caimito*, *fruta bomba*, *pomarosa*, *chirimoya*, *anón*, *guanábana*, prunes, guavas, grapefruits, tangerines, plantains, and coconuts, as well as wood trees such as *júcaro*, *guásima*, *guamá*, eucalyptus, mahogany, and others.

The twenty-seven hectare farm was inhabited by twelve family members, six of whom help in the farm sporadically, and four (two men and two women), who work on the farm on a daily basis. Just as in Francmacio's case, the main household is where Jacinto lives. Here is where organization of production, negotiations with state officials, and surplus appropriation take place, led by him.

Jacinto has a six-inch oil-powered turbine which was not been in use between 1993 and 1995 for lack of fuel. His tractor, however, was used often and plays an important role in tilling between the mango trees. Among other tasks, the tractor was used to mix the soil with organic debris, improving its humidity and fertility.

Private production and appropriation of the surplus allows small farmers to be flexible to the vagaries of weather and state policies. In order to produce food crops that became scarce through the state allocation system after the beginning of the "Special Period," both Francmacio and Jacinto cleared new patches by cutting or trimming trees. Francmacio pruned every other tree line and planted yucca, rice, and other food crops between the mango trees. Jacinto cleared a half hectare and planted corn, pumpkins, sweet potatoes, and rice. He also increased the number of cows, pigs and fowl on the farm.

Besides changing his technology of production, Francmacio has experimented with products which he did not produce before, such as wheat and peanuts. The scarcity of cooking oil associated with the "Special Period" prompted him to plant peanuts from which he extracts more than thirty pounds of oil, three times a year. He also produced two quintals of wheat. Because of his experience working in the state's industrial sector, Francmacio was able to design and build a simple grinding machine in his friend's shop, which he now uses to grind everything from wheat to sugar cane. This machine allows him to grind the ingredients to produce *gofio* (a snack made from ground wheat), and animal feed from rice chaff, peanut hull, and mango seeds.

Private Rights and Small-Scale Technology

Private property rights allow and encourage small farmers to experiment and develop technologies that are uniquely suited to the specific characteristics of particular fields (e.g. planting beds and grafting). Small farmers appropriate their own surplus, consume part of it, and transfer part of it to the state. They also share it with their neighbors and extended families, or exchange some of it for valued goods. Control over the surplus (as well as the relatively high degree of autonomy in decision making, the security provided by their productive unit, and the transferability of their assets to their children), gives small farmers ample reward and reason to maintain the long-run sustainability of their resource base.

Their limited access to modern inputs prompted small farmers to further develop traditional, "organic" methods. Small farmers utilize numerous techniques and produce a wide variety of output combinations, while using less chemicals, machinery, and equipment per unit of arable land, and more labor than state farms and cooperatives. Small farmers attempt to maintain and increase the value of their natural resources in several ways. They increase local biodiversity by planting assorted crops and plant va-

3. Jacinto has four varieties of oranges: *agria* (bitter), *chinas*, *nevo*, and *valencia*.

rieties. With time, biological diversity and intercropping in "alley" and "mosaic" patterns results in feedback effects between plants, predators and pests. Furthermore, individual farmers carry out labor-intensive, anti-erosion measures. The high labor-to-land ratios increase the productivity of these systems, and the small number of resource users on each farm allow for the enforcement of sustainable resource-use norms. Small farmers have an intimate knowledge of their land and the interaction between crops, soils, fertilizers, pests, and pesticides. They are keenly aware of the processes of land degradation and diligently engage in activities aimed at restoring and protecting soil fertility. Their agricultural systems exhibit high resiliency, allowing them to adapt to cumulative stresses and sudden shocks upon the sensitive ecosystems of Santo Domingo.

PRODUCTION COOPERATIVES (CPAS)

The government's movement towards the formation of production cooperatives, which began in 1977, aimed to increase output by modernizing peasant production and to increase state control over the country's output mix and its distribution. The incentives for small farmers to pool their land and labor included preferential access to credit to buy capital inputs at subsidized prices and retirement benefits (Deere, Meurs and Pérez 1992:121).

Cooperatives combine state and group control with peasant farming culture, resulting in productive systems that exhibit some characteristics of both modern and traditional farming. In general, cooperatives exhibit higher degrees of mechanization, use of chemicals, irrigation equipment, and productive specialization per unit of land, than individual producers, but less so than state farms.

In terms of their institutional arrangement, cooperatives are structured as a common-property regime. As such, the land and other productive assets are owned by cooperative members and the surplus product is appropriated collectively. Cooperative members can transfer their membership to their children, and thus the right to belong to the cooperative. The main production decisions are made collectively at monthly meetings led by the internally-elected council. Whereas self-provisioning schemes were introduced in state farms during the "Special Period," cooperatives have always (since their creation) produced for their own consumption, in addition to selling the bulk of their output to the state. Much of the production of meat, vegetables, plantains, and tubers is sold to cooperative members for self-provisioning. Just as in the case of individual farmers, these rights motivate cooperative members to protect their natural resources.

However, the range of cooperative property rights is limited by the cooperative's relationship with the state agricultural ministries. The state controls the allocation of inputs and credit to the CPAs, and has a heavy hand in determining the technology of production. The state also controls the prices of output and contracts the amounts to be sold to the state, and can pressure cooperatives to make certain investments.

The "Mariana Grajales" CPA

Most of the original members of this CPA were once individual farmers who pooled their land to join the cooperative. On the other hand, three of the main managers previously worked for the state sector before joining the CPA. The cooperative's stock of cattle has grown consistently, going from 100 in 1987 to 864 head in 1992, to more than 980 in 1995. In 1993, this CPA cultivated 323 hectares of land, with the remaining 957 hectares dedicated to cattle production.

The CPA's production Chief, Ernesto Sutil, calculated that 90% of their area is sandy soil. There are some good soils in the Mordazo area (carbonated-dark and red-ferralitic soils) but are extremely prone to flooding (Sutil 1993). The "Mariana Grajales" is located in, what an official from the National Enterprise for Agricultural and Cattle Projects (ENPA) described as, a geological "drain" or lowlands that are prone to severe flooding (Choy 1993). Several creeks pass through the CPA which, in periods of intense rain, flood several areas of the cooperative. To deal with their flooding problems, they have built canals surrounding their main fields. These canals help both by collecting the water that comes from outside of the cooperative, and by draining its own fields. According to Sutil, solving the drainage problem would allow for more production and for more people to join the cooperative.

The cooperative exhibited some of the practices associated with small, alternative farming namely, the use of organic fertilizers, and innovative soil preparation and rotation techniques. Some fields in the plantain area have been improved with chicken manure, produced in their own chicken compound. Around 135 hectares are rotated between cattle ranching and cropping. Crop residues are left in the tilled fields, increasing the potassium contents of the soil and improving its structure. Corn is planted in areas where potatoes are grown to fixate nitrogen. Animal traction is routinely used in the CPA. In 1992, the cooperative had eleven teams of oxen and eight tractors.

While soil preparation procedures in the cooperative are similar to those in state farms, the cooperative has developed norms to prepare the soil in innovative ways in some areas. In fields of low soil depth, crops are planted in mounds (for plantains) or in humps (for potatoes) that are made of topsoil. These techniques also help crops survive waterlogging, especially in areas where hardpan is present in the subsoil. According to Menéndez (1993), these techniques have notably improved the production of plantains.

The "Mariana Grajales" CPA is a good example of the control and limits imposed by the relationship between cooperatives and the central government in Cuba. In an attempt to acquire the equipment and infrastructure needed to increase production, CPA leaders sought to join the "campaign for the 100,000 quintals." In exchange for state investment, inputs, and technical assistance associated with this campaign, the CPA submitted itself more fully to the production targets, infrastructural design, and directives of the Ministry of Agriculture. Several departments of the Ministry of Agriculture, namely the ENPA, Soils and Fertilizers, Plant Health, and the municipal office of the Ministry, crafted a five-year plan for development of this CPA. The plan lays out specialization and rotation schemes by area, and the kinds of infrastructure investments required.

The most important infrastructural investment in the plan is the installation of Fregat machines to irrigate fifty hectares of land for sixteen hours per day. Since there had been problems with Fregat machines in the ECV Manacas, the Ministry of Agriculture undertook 50% of the investment costs. Thanks to this new irrigation system, the cooperative can plant three crops a year in the areas benefited. The crops planted in these areas are potato, plantain, cucumber, pumpkin, rice, and sweet potato. Potato yields increased from between 75 and 150 quintals per hectare in 1986 to 535 quintals per hectare in 1992, much of it due to the irrigation equipment. The average (national) returns are between 300 and 335 quintals per hectare.

However, the MINAGRI had not provided the technical assistance and resources needed to carry out the circular draining system of canals that goes along with Fregat irrigation. In 1993 the CPA still had a traditional drainage system based upon simple canals. As a result of the Fregat machines and the lack of adequate drainage, the affected fields became more prone to flooding, and the productive system more sensitive to rain. Drainage is a key component of the project, for it could prevent the worsening flooding and waterlogging, and thus is very important for soil conservation.

ENPA officials admit that this irrigation technology may worsen erosion and drainage problems, but the responsibility for conservation is placed solely in the hands of workers. ENPA officials emphasize that irrigators must be very disciplined in following the technical specifications and water application norms; in order for the Fregat system to work it must be properly managed. The solution, however, resulted in another degradation problem. Whereas by 1995 a circular drainage system had been finished, this required changing the direction of the furrows, which now follow the heading of the slope and which has lead to soil erosion. In addition, because of the limited amount of water that may be extracted from wells, in 1992 the state authorized increases in the extraction of water from underground sources for the crops projected in the plan only (and not for self-provisioning crops).

It is clear that the state exerts a great deal of control over the CPA. Moreover, because of the changes towards modern farming methods, these cooperativists face problems that they did not have as family farmers (e.g., persistent pest problems). Yet the cooperative maintains many aspects of the family-farm culture in the context of a systematic cooperative system. Giraldo Pérez is quick to point out that CPA members work for themselves and that this autonomy makes a difference; "People here work with interest and, because there is love for the land and the cooperative, things are done well. If there are pests it is quickly discovered and dealt with. The cadres and workers have responsibilities and the liberty to make decisions. This power leads to success" (G. Pérez 1993).

The "Nelson Veitía" CPA

With 613 hectares, the CPA "Nelson Veitía" has half the land area of the "Mariana Grajales" and fifty four members. It had 300 hectares of grazing land, 242 hectares planted in tubers and legumes, and four hectares of trees. Agricultural production in this cooperative has characteristics of both the alternative and the modern farming models. Whereas only one of the founding members had a tractor before the formation of the cooperative, by 1993 the cooperative had six tractors. Still, soil preparation with heavy equipment is kept to a minimum. Relay cropping and some inter-cropping were used to maintain soil fertility. The "Nelson Veitía" exhibits more agro-diversity than the "Mariana Grajales."

The cooperative's irrigation infrastructure includes two small dams, five turbines, one deep water well with a pump, a system of tubes and canals, and other equipment. There have been saline intrusions in some of their wells, probably due to the heavy extraction of water by state farms in the area and to the damming of the Alacranes river, which reduces the recharge in underground wells in the area. The CPA uses portable sprinklers and sometimes traditional irrigation. This cooperative also has urgent flooding and drainage problems.

The dark soils of this CPA are better than the sandy soils that prevail in the rest of the municipality. The cooperative has more than 500 hectares of dark soils, 54 hectares of sandy soils and 15 hectares of red soils. Dark soils are more fertile than other soils in the area and are therefore used constantly. Notwithstanding this, the MINAGRI regards the "Nelson Veitía" as a low-productivity cooperative. Some members interviewed argue that the cooperative has not received sufficient state support. In part as a consequence of its low profitability, cooperative members feel compelled to use the most productive areas more intensely. In addition, farming methods have changed greatly since the cooperative was formed. While there is some intercropping and crop rotation, the farm's layout is a far cry from the mosaic and alley patterns found in individual farms. There is no emphasis on agroforestry. Rather, the cooperative was slowly moving towards monocropping, yet it faced difficult pest-problems and *marabú* infestations.

Interestingly, the MINAGRI has not aggressively searched for ways to deal with pest problems in this cooperative in an integrated way. And in 1993 the coop had no access to biological pest controls produced in state-sponsored laboratories but rather, it relied on chemical pesticides with little success. CPA members are concerned that pest problems increasingly limit what they can produce. Because of pest problems, the CPA agreed with the MINAGRI to limit production of cucumbers and pumpkins and not to produce onions in 1992. Cooperative members wonder whether it would be in their best interest to stick to cattle ranching. Cattle production is less complex and would increase their profitability and the stability of output and earnings. However, it can have a negative impact upon the soil, a fact not explicitly considered by the members interviewed.

The "Nelson Veitía" still produced multiple crops; some are produced in intercropping patterns, but not in the "mosaic" or multiple-patch layouts that are typical of small farms. Some fields are set aside and used as pastures for horses and some crops are rotated, however Navias admits that crop rotations, along with soil preparation and conservation activities, are not carried out in a systematic way. Moreover, while CPA members are not too concerned with soil degradation, some forms of degradation are evident. As in the rest of Santo Domingo, flooding affects the "Nelson Veitía" and is partly the result of deforestation. Yet while more than half of the cooperative's area is used for raising cattle, less than 1% of the area is planted with trees.

SUMMARY AND CONCLUSIONS

Agricultural ecosystems in Santo Domingo are very sensitive as they change easily and drastically after human intervention. However, they exhibit high resilience, as they respond favorably to soil amendments, appropriate humidity, fallow periods, small scale reforestation and polycropping.

State farms in Santo Domingo conformed to the modern model of farming. They were large farms that base their productivity on monocropping, chemical pesticides, fertilizers, use of heavy tilling equipment, modern irrigation equipment and no fallow periods. State farms make little use of intercropping, agroforestry, crop rotation, and other alternative technologies. Alternative fertilizers are used but their supplies are limited by the reluctance of administrators to assign more workers and resources to their production.

The use of modern farming technologies in the context of state agriculture led to resource degradation in Santo Domingo. The heavy use of fertilizers in the area is responsible for water contamination with nitrate. Large-scale use of traditional irrigation led to erosion and leaching, and modern irrigation systems have only contributed to these trends. The use of heavy equipment has led to soil compaction and has prevented basic anti-erosive measures. Monocropping has fostered erosion and pest problems, and has made fields more prone to flooding.

Inevitably, resource degradation reduces overall productivity, which compels enterprise managers and state officials to try to improve upon the modern techniques used, with more heavy equipment and infrastructure. State farms were understaffed, due to the lack of attractive worker incentives. The lack of an adequate number of steady workers meant that crops did not receive the attention that they needed. To counter this, state farms planted larger areas which reduced labor inputs per unit of land. As a result of this and the degradation of the resource base, total output stagnated. Managers had very limited awareness and sought no information about the degrading impact of their productive practices. Instead, they perceive the resource base as naturally poor.

Small farmers' agricultural systems take advantage of restorative potential of the resource base and are therefore very resilient. They have the incentives to spend long hours in the fields, where they constantly monitor and gather information on the condition of plant, tree, soil and water resources. In general, small farmers exhibited more awareness of degradation problems than did cooperative members. Small-farmers have greater incentives to seek and use information about their resource base. CPA members emphasized the importance of chemical fertilizers and drainage works over the integration of production and conservation activities.

Labor-intensive, small-farming techniques combine modest amounts of agrochemicals, small tractors, and irrigation equipment, with traditional methods. As a result, they generate proportionally less pollution and soil degradation by compaction, salinization and acidification than large-modern farms. Small farms in Cuba promote biodiversity, as they produce more than thirty agricultural and livestock products each, and dozens of different sub-species. They employ a variety of productive techniques in agrosilvipastural patterns. Monocropping makes no sense for them. All private producers interviewed experiment with different technologies. They have ample space for experimentation, as their families have access to nearby schools and medical doctors, they appropriate their own surplus, and the farm's output has secure, stable markets and prices. These conditions enable the farmer to administer and control production and invest his time and effort in the development of the farm.

Cooperatives possess more machinery and irrigation equipment, they use a greater amount of chemicals, and have a higher degree of specialization than individual producers. Many cooperative members seem to be convinced that the net benefits of adopting modern inputs are high. State farms, however, are more advanced in this sense. On the other hand, cooperatives make more use of alternative fertilizers, pesticides, and tilling techniques than state farms do. In general, CPAs develop rotation schemes that best suit their soils and output mix. CPAs are no longer formed mainly by former individual farmers, as many former state-farm technicians and field workers have joined them and, in some cases occupy administrative and managerial positions. This interaction facilitates the merging of modern and traditional farming techniques.

Judging by the characteristics of each form of organization of production, the productive system of small farms are less sensitive and more resilient than those of cooperatives and state farms (the latter displaying the highest sensitivity and lowest resilience of the three). In terms of their institutional arrangements, the evidence presented here suggests that small farmers have incentives and use technologies that enable sustainable resource management.

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