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LAND CAPABILITY ASSESSMENT FOR A SMALLHOLDERS SETTLEMENT SCHEME IN JAMAICA

WIM ANDRIESSE and JULES J. SCHOLTEN
International Soil Museum, Wageningen (The Netherlands)

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ABSTRACT

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In the framework of the land-reform programme in Jamaica, a detailed quantitative land capability assessment was carried out in order to determine viable land uses and related farm sizes for the development plan of a smallholders settlement. The assessed area (Burnt Ground) is located in western Jamaica. It consists of two landforms, both developed in limestone: an undulating erosion surface with deep, acid soils (Orthoxic Palehumults) surrounded by steep-sided hills with shallow, stony soils (predominantly Lithic Tropudalfs). The land capability assessment of the area is based on the principle of Land Utilization Types (LUT's) as subjects for classification. Three viable LUT's were determined and specified in line with government policy, socio-economic considerations and traditional land uses in the area. Farm inputs and outputs were quantified and a maximum productivity value (added value expressed in dollars per hectare) was established for each LUT. Next, the requirements of each LUT were matched against a number of diagnostic land characteristics which are related to the soils and topography. This approach has the practical value that, once the target farm-added value per year is established per LUT, the corresponding minimum viable farm size can be determined for land without limitations and for land with various degrees of limitations to that use. This is done by dividing the target farm-added value by the hectare productivity value. The approach also permits a direct quantitative comparison between productivities of different LUT's.

INTRODUCTION

Lands acquired by the government of Jamaica for its land reform programme are subdivided for long-term lease or sale to small farmers. In the preparation of development plans for these areas (settlement schemes), quantitative land capability assessment plays an important part, because it helps to determine relevant and promising land use alternatives and related minimum farm sizes.

The aim of this paper is to provide an example of practical interpretation of soil information, in relation to other physical and socio-economic data, for rural land use planning.

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DESCRIPTION OF THE STUDY AREA

Location

The study area is the Burnt Ground settlement scheme located in the parish of Hanover in western Jamaica, approximately 25 km southwest of Montego Bay along the main road to Savanna-la-Mar (Figs. 1 and 2) at latitude 18°22′N and longitude 77°59′W. The total area measures 709 ha and is being developed by the government for settlement of small farmers, including the development of the necessary physical and social infrastructure.

Climate

Rainfall data are available for a recording station (Shettlewood) approximately 2.5 km east of Burnt Ground at an elevation of about 150 m above mean sea level (Table I). The elevation of Burnt Ground ranges from 170 to 340 m above mean sea level (MSL).

Evaporation (A pan) was measured at Smithfield station, approximately 14 km northwest of Burnt Ground at 270 m above MSL. Table II shows the mean monthly and annual evaporation and the calculated reference crop evapotranspiration (evapotranspiration = 0.75 × pan evaporation).

Van Zel (1979) has carried out an analysis of the rainfall (Shettlewood) and evapotranspiration (Smithfield) data in order to estimate irrigation needs in the Burnt Ground setting. This analysis (Fig. 3) shows that, even at 90% chance of occurrence, rainfall during the period from May to November is sufficient for rain-fed agriculture. The length of the rainy season permits rain-fed agriculture of two consecutive crops with a short to medium growing period. The December—April period is not as wet and does not allow successful cultivation of rain-fed annual crops. Grass (pastures) and deep-rooting crops (e.g. fruit trees) can be grown however, provided they are established in the wet season.

Mean daily minimum and maximum temperatures range from 20° to 28°C as recorded at Smithfield for the period 1970—1978.

Based upon the above data, the climate of Burnt Ground can be classified as Af according to the Köppen system of classification (Köppen, 1931).

The soil moisture regime of the area is classified as udic in terms of the USDA Soil Taxonomy (Soil Survey Staff, 1975) because rainfall exceeds evapotranspiration throughout the year (Tables I and II). The soil temperature regime is postulated to be isohyperthermic.

Physiography

The Burnt Ground area is underlain by the White Limestone Formation (Lower Miocene to Middle Eocene) which consists of hard, subhorizontally bedded limestone with inclusions of flint.

Two major landforms can be distinguished: i) an undulating to rolling

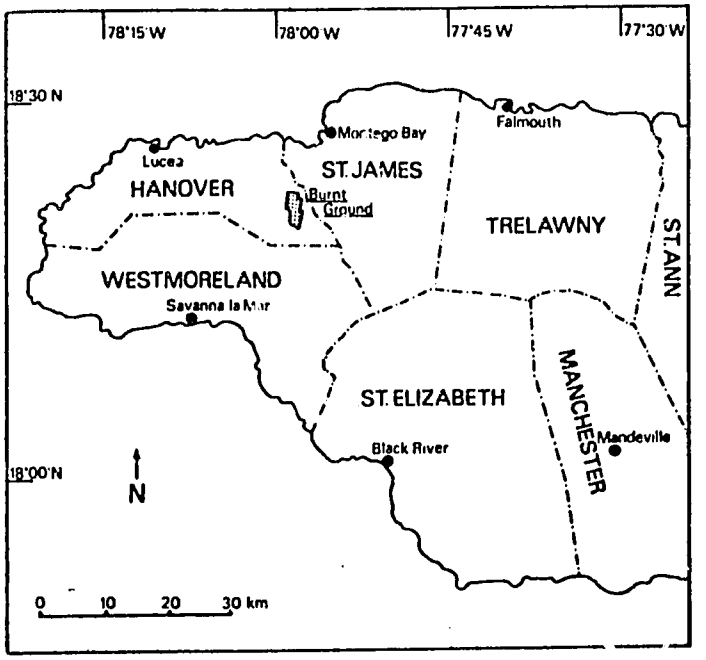

Fig. 1. The Burnt Ground area in western Jamaica.

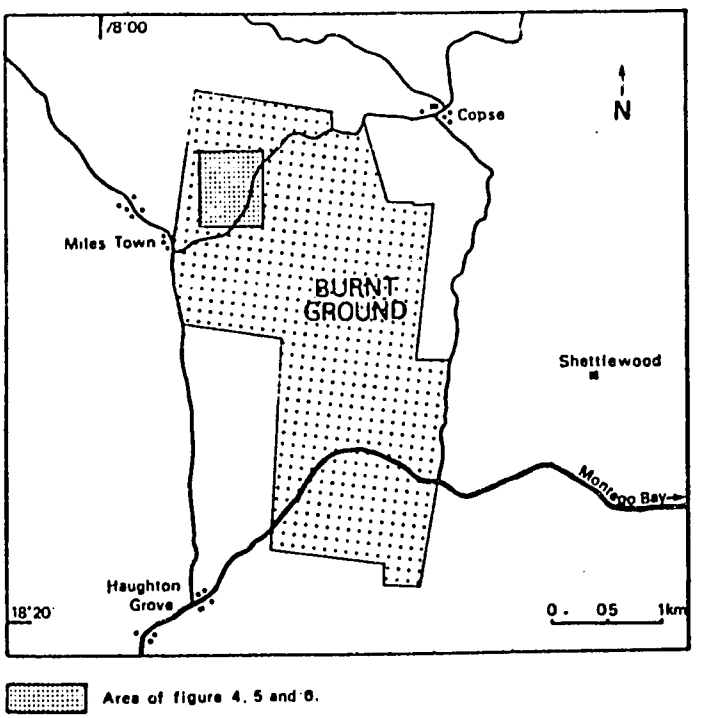

Fig. 2. The setting of the Burnt Ground settlement scheme and location of Figs. 4, 5 and 6.

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TABLE I

Mean monthly and annual rainfall (mm) at Shettlewood (1931—1978)

Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
86.4	86.4	96.5	190.5	354.4	276.9	246.4	299.7	302.3	320.3	147.3	86.4	2484.2

TABLE II

Mean monthly evaporation (mm) and calculated evapotranspiration (mm) at Smithfield (1970–1978)

	Jan.	Feb.	Mar.	Apr.	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	Year
Evaporation	88.9	94.0	114.3	137.2	129.5	132.1	139.7	127.0	119.4	99.1	91.4	94.0	1366.6
Evapotranspiration	66.7	70.5	85.7	102.9	97.1	99.1	104.8	95.3	89.6	74.3	68.6	70.5	1025.1

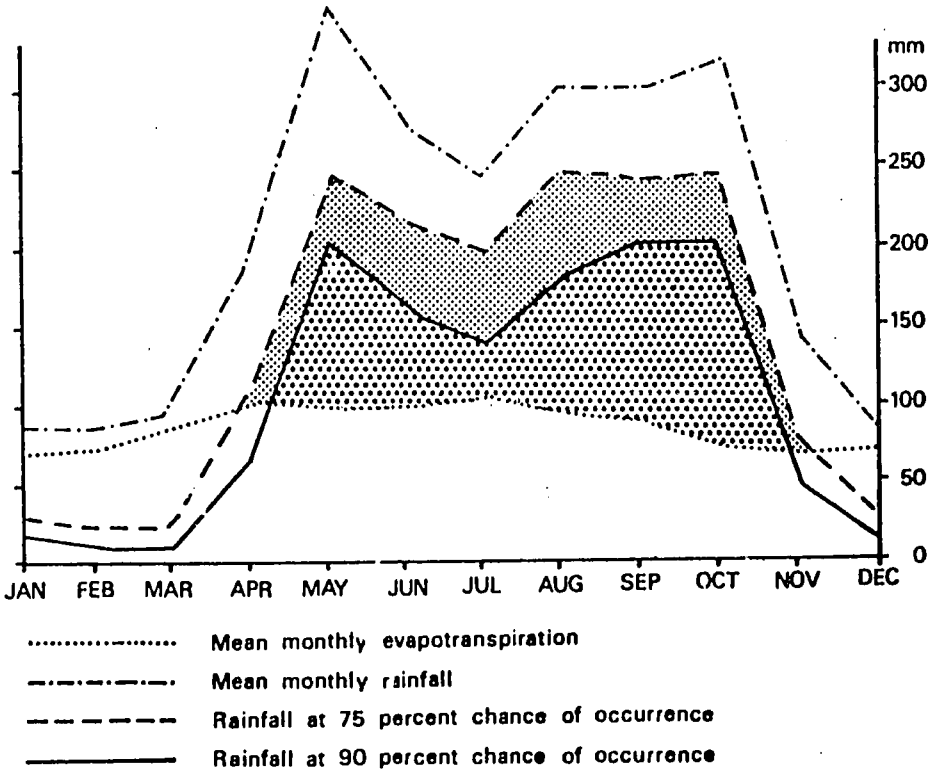

Fig. 3. Monthly rainfall and evapotranspiration pertaining to the Burnt Ground setting.

dissected limestone plateau (erosion surface); (ii) predominantly steep-sided limestone hills. The transition between the two landforms is abrupt. The dissected limestone plateau comprises nearly 80% of the total area. The range in elevation is between 170 and 260 m above MSL. The slopes are predominantly less than 15° (27%) with the majority being less than 7° (12%), see Table III. Subterranean dissolution of the limestone rock has resulted in sinkholes and depressions at the surface which usually are surrounded by steeper slopes. The sinkholes and depressions measure from a few meters to 100 m in diameter. Short and shallow gullies channel run-off into many of the sinkholes and depressions. Few gullies are longer than 500 m. Only the longest waterway in the area has a distinct flood plain, with a width up to 100 m in places. All surface drainage is intermittent.

The steep-sided limestone hills occupy slightly more than 20% of the area, mainly in the northern portion. They reach elevations of up to 340 m above MSL. Slopes are mainly steeper than 30° (58%) with the notable exception of small saddle areas that have slopes of less than 15° (27%). The hills occur as individual masses of elevated land (inselbergs) surrounded by the limestone plateau.

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TABLE III

Distribution of slope classes in the Burnt Ground area

Slope class (degree)	Slope class (percent)	Percent of area
0– 7	0–12	47.1
7–15	12–27	31.5
15–20	27–36	2.6
20–25	36–47	2.4
25–30	47–58	0.1
>30	>58	16.3
		100.0

Soils

In the area a total of 8 soil pits were described, sampled and analyzed and an additional 69 augerhole observations were made. From these observations and available analyses it appears that the dominant soil occurring on the dissected limestone plateau is deep, well-drained, strongly acid and well-structured. The surface layers (ochric epipedons) are dark brown, dark grayish brown or dark yellowish brown clays with moderate to strong blocky and crumb structure and with relatively high content of organic carbon (more than 1.5% and up to 11%). The high organic carbon levels may be related to the long history of pasture management in the area. Deeper layers (argillic horizons) are yellowish brown to strong brown heavy clays with moderate to strong blocky structure. Clay increase is perceptible (10–20%) and does not decrease by more than 20% from its maximum within 150 cm of the soil surface. Well-developed clay cutans were observed in the field and micromorphologically, in thin sections. Organic carbon content gradually decreases with depth but is still high (0.9% or more) in the upper part of the argillic horizon. The clays have low activity with CEC's (NH_4OAc, pH 7) less than 24 meq./100 g clay and effective CEC (sum of bases extractable with 1 *N* NH_4OAc plus aluminium extractable with 1 *N* KCl) less than 12 meq./100 g clay. Kaolinite is the largest component of the clay fraction, followed by 2:1 and 2:1:1 layer minerals (vermiculite–chlorite), quartz and goethite. Base saturation (by sum of cations) drops with depth and is less than 35% in the argillic horizon. Consequently, these soils are strongly to very strongly acid (pH H_2O 5.5–4.5). The classification at family level, according the USDA Soil Taxonomy (Soil Survey Staff, 1975) is: Orthoxic Palehumult, clayey, mixed, isohyperthermic (Scholten and Andriesse, 1982). In some depressions on the limestone plateau, gravel and stone contents of weathering flint may be more than 35% and such soils belong to the clayey-skeletal family of Orthoxic Palehumults. In depressions that are subject to severe flooding up to several

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months a year, soils are moderately well drained and genetically less developed. These soils were identified as Aquic Oxic Humitropepts, very fine, kaolinitic, isohyperthermic (Rural Physical Planning Unit, 1979).

The soils of the limestone hills can be divided into those of the predominantly steep side slopes and those on the gently sloping saddle areas. They all have slightly acid to neutral reactions (pH 6.0—7.5). On the steep slopes soils are mainly shallow (contact to the limestone within 50 cm from the surface), stony (more than 35% rock fragments in the solum) and rocky (more than 20% outcrops). These soils have well expressed (dark) yellowish brown argillic horizons with moderate to strong blocky structure and distinct clay cutans. Most soils have an ochric epipedon. They were classified as Lithic Tropudalfs, clayey-skeletal, mixed, isohyperthermic. Some soils have surface layers that meet the requirements for mollic epipedon: Lithic Argiudolls, clayey-skeletal, mixed, isohyperthermic (Rural Physical Planning Unit, 1979). The soils of the saddle areas are developed on colluvium from limestone and its weathering products. They are deep and well drained and have moderate to strong blocky structure. They have very dark grayish brown to dark yellowish brown clay surface layers (ochric epipedons) overlying yellowish brown heavy clays (argillic horizon): Typic Tropudalfs, very fine, mixed, isohyperthermic (Rural Physical Planning Unit, 1979).

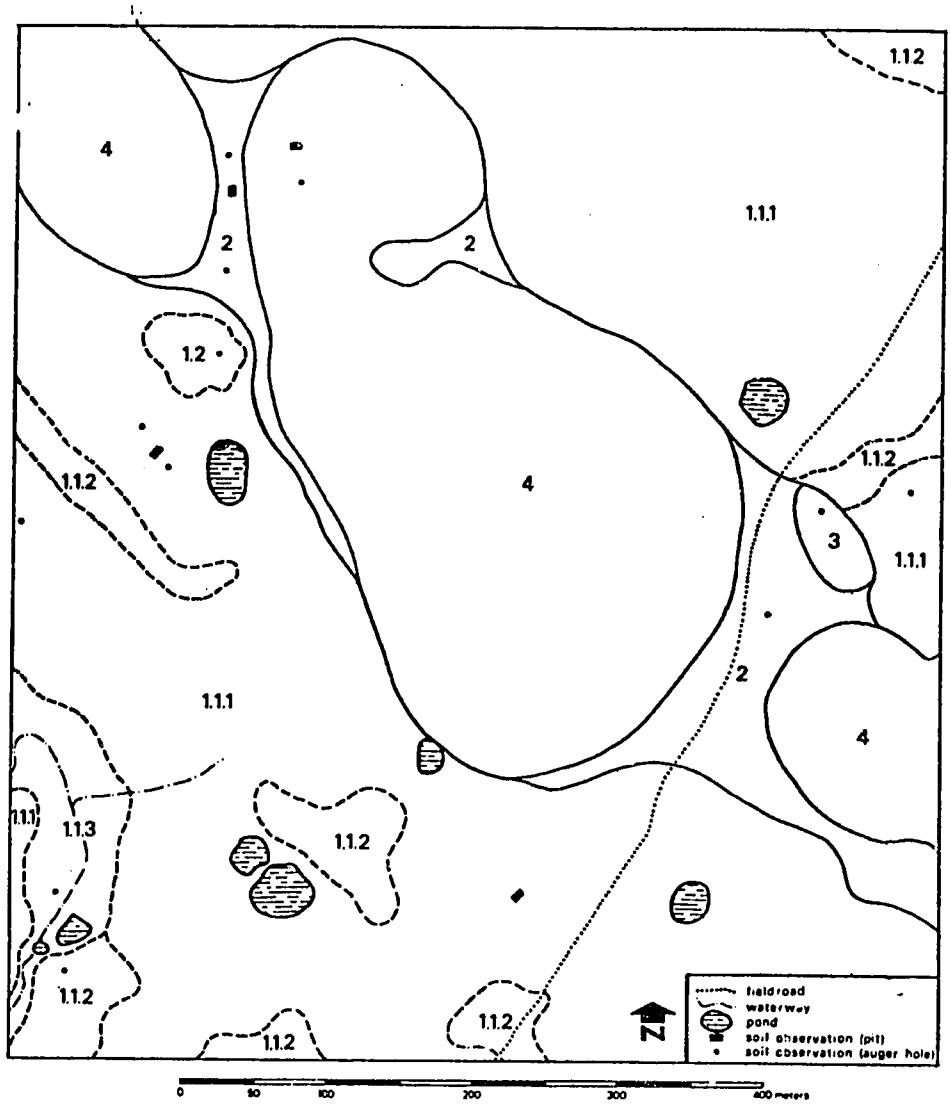
Fig. 4 shows the distribution of most of these soils in a section of the Burnt Ground area.

Vegetation and land use

The Burnt Ground area is a traditional pasture area. Before 1980, when settlement of farmers in smallholdings commenced, most of the undulating to rolling land of the property (500 ha or about 70.5% of the total area) was under pasture. Under the management of a government agency, about 1240 head of cattle were kept in the area. Part of the pastures has been improved by means of planting Pangola (*Digitaria decumbens*), Guinea (*Panicum maximum*), Napier (*Pennisetum purpureum*) and Paragrass (*Brachiara mutica*). A network of stone walls, wire fences and gates subdivides the pastures into grazing enclosures. Drinking water for the cattle is available from several natural depressions and artificial ponds (total area of the ponds is 10 ha or 1.4% of the Burnt Ground area). Scattered over the pastures, individual mango (*Mangifera* spp.), citrus, star apple (*Chrysophyllum cainito*) and cotton trees (*Ceiba pentandra*) provide shade to the cattle. Most of the hilly and steep parts of the property (150 ha, or 21.2% of the area) is covered by forest and bush vegetation.

A citrus orchard of approximately 29 ha (4.1%) was established in 1953, on both sides of the main Montego Bay–Savanna la Mar road.

Small patches of land, covering a total of about 9 ha (1.3%), mainly occurring in the isolated interior valleys in the steep limestone hills, are being cultivated to yam (*Dioscorea* spp.), dasheen (*Colocasia esculenta*), banana



Map unit no.	Parent material	Land form		Map unit name	Slope
1.1.1	Residuum from limestone and flint	Limestone Plateau	Dissected erosion surface	Orthoxic Palehumult clayey mixed isohyperthermic undulating phase	0 - 7°
1.1.2				Orthoxic Palehumult clayey mixed isohyperthermic rolling phase	7 - 15°
1.1.3	Residuum and colluvium from limestone and flint		Flood plain of intermittent stream	Orthoxic Palehumult clayey mixed isohyperthermic, nearly level severely flooded phase	0 - 2°
1.2			Depression in erosion surface	Orthoxic Palehumult clayey-skeletal mixed isohyperthermic nearly level slightly flooded phase	0 - 2°
2	Colluvium from limestone and flint	Limestone Hills	Saddle areas	Typic Tropudalf very fine mixed isohyperthermic sloping slightly gravelly phase	0 - 15°
3	Residuum from limestone and flint		Hillside slopes	Lithic Tropudalf very fine mixed isohyperthermic sloping phase	7 - 15°
4				Association of Lithic Tropudalf clayey-skeletal mixed isohyperthermic and Lithic Argiudolf clayey-skeletal mixed isohyperthermic steeply sloping phase	15 - 40° mainly over 30°

Fig. 4. Soils of a section of the Burnt Ground settlement scheme.

(*Musa* spp.), sugarcane (*Saccharum* spp.), coconut (*Cocos nucifera*), marihuana (*Cannabis sativa*), etc. by people living near the property. Also, newly settled farmers have started to prepare backyard gardens (approximately 0.14 ha each) in the area.

The remainder of the area (11 ha, or 1.5%) is occupied by permanent structures such as houses, cowsheds and cowpens, a concrete-surfaced water catchment with a storage tank and a few roads including part of the main road from Montego Bay to Savanna la Mar.

Land tenure

Historically, most of the region including Burnt Ground was farmed in large private holdings concentrating on beef cattle production. With the introduction of land reform, many of the large holdings were acquired by the government for subdivision among local landless small farmers in units of less than 5 ha in a system of leasehold or, since 1981, also as freehold. In some of the new schemes the farmers were settled in small villages but for the Burnt Ground area individual dispersed settlement has been selected for the establishment of dairy smallholdings. The settlements are equipped with the appropriate physical and social infrastructure, including farm roads, farm houses, water and electricity supplies, communal facilities, credit facilities, etc.

A number of privately owned large holdings of more than 50 ha continues to operate successfully in the region. They are either beef cattle or dairy farms.

LAND CAPABILITY ASSESSMENT

Objective

The main objective for the execution of a detailed quantitative land capability assessment of the Burnt Ground settlement scheme was to find a key to equal and fair subdivision of the cultivable land into individual farms capable of producing a viable target-income for farmer-settlers.

Method

The assessment was done in steps. First, relevant types of agricultural use or Land Utilization Types (LUT's) had to be defined for the area. The model of these LUT's is a simplified version of the concept of LUT's developed in the Land Evaluation approach (Beek and Bennema, 1971; Beek, 1974, 1978; FAO, 1976). The LUT's in the Burnt Ground example were characterized in terms of their produce (e.g., milk), their level of management (e.g., traditional family-operated smallholdings under rain-fed conditions) and related inputs (e.g., fertilizers).

The second step involved quantification of the inputs and outputs per LUT and determination of a maximum productivity per hectare which in the case

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of Burnt Ground was expressed by the added-value-factor share (added value is total value of output minus non-factor costs).

In the third step, the specific requirements of each LUT were matched with the physical land conditions occurring in the Burnt Ground scheme. These land conditions were inventoried in a detailed general-purpose soil survey involving slope analysis in the office plus field observations and laboratory analyses on samples from genetic horizons in eight soil pits. The results of the survey were presented in the form of a detailed soil map (see Fig. 4) with map units derived from taxonomic units at the family level of Soil Taxonomy (Soil

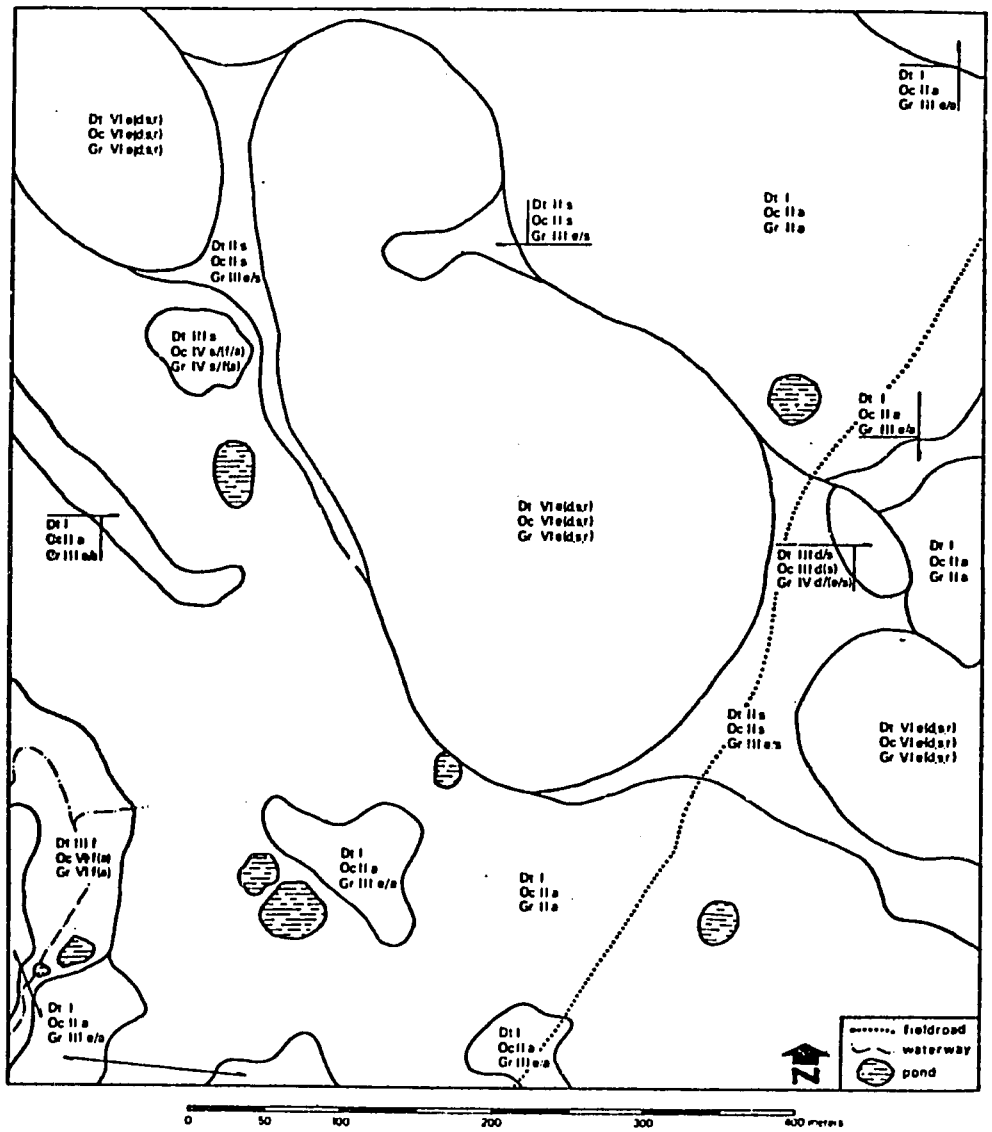

Fig. 5. Land capability of a section of the Burnt Ground settlement scheme (explanation of classification formula in text).

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Survey Staff, 1975). Then, the soil map units were grouped into units of "land capability classes" and "subclasses" according to physical limitations ("diagnostic land characteristics") relevant to the various LUT's (Fig. 5). Land capability classes group tracts of land (e.g., soil map units) pertinent to quantified increasing degrees of limitation (e.g., 10% reduction in output for Class II land compared with Class I land). Land capability subclasses group tracts of land according to the various kinds of limitations (e.g., slope, soil acidity). It should be noted that, in the Burnt Ground example, land characteristics were selected rather than land qualities as the diagnostic physical limitations for matching with the LUT requirements. Although land qualities, as defined by Beek (1978), are better able to describe the relationship between environment and land use performance, single land characteristics were preferred because they can be derived directly from the soil map and their quantification is simpler than those of complex land qualities.

In the fourth and final step, minimum farm sizes were determined for the individual LUT's based on the productivity per hectare for each land capability class. The farm sizes were calculated so that they could generate the target farm income (or target farm-added value) which was established as a matter of government policy. This final step formed the basis for the land use planning and farm lay-out on the Burnt Ground settlement scheme (see Fig. 6 and the section on "Application of the Results").

Relevant land utilization types (LUT's)

Land utilization types relevant to the Burnt Ground settlement scheme have been selected and defined on the basis of the following factors: (a) government land use policy towards agricultural production in the region; (b) present land use and agricultural produce; (c) prevailing farm management level and technical knowledge in adjacent areas; (d) farm size and land tenure conditions; and (e) marketing aspects.

The first LUT selected deals with dairy farming. The presence of a dairy plant nearby Burnt Ground (10 km), a favourable milk price and the existing land use in the project area (mainly pastures) provide good prospects for dairy farming. Also an agricultural training centre in the vicinity (5 km) can provide training and technical support to selected farmer-settlers.

As the Jamaican government is implementing a resuscitation programme for citrus and citrus marketing prospects are good, citrus production was selected as a second LUT appropriate to the citrus orchard existing in the area (28 ha).

Further, backyard gardening of annual crops and vegetables is a relevant land utilization type inasmuch as most prospective farmer-settlers have experience in this kind of farming.

Produce is one of the attributes related to the determination of LUT's. Other attributes are the size of the farm, land tenure and farm management level. The land reform programme of the government aims at providing viable farm units to landless small farmers living in the vicinity of the project area. Thus,

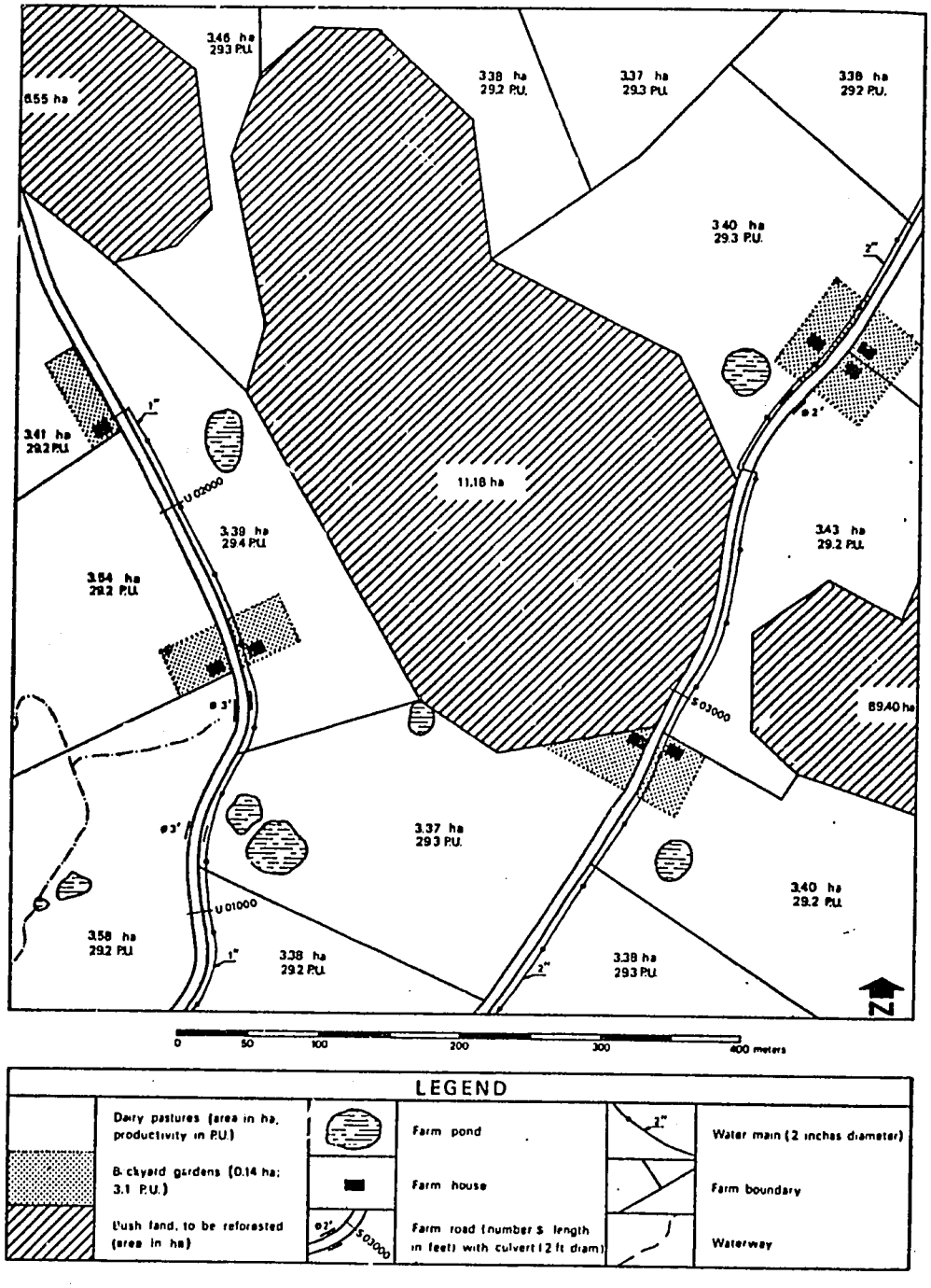

Fig. 6. Development plan of a section of the Burnt Ground settlement scheme showing the lay-out of farms, land for reforestation and infrastructure.

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farm size is small by definition. Farms are considered economically viable if farm-added value exceeds J$ 3200 per year at the price levels of February 1977. This date was chosen as a standard reference for all calculations of added value in order to allow direct comparison of productivity of different LUT s. At February 1977, J$ 1.00 was equal to US$ 1.10. (First Rural Development Project, 1977.) Depending on the kind of land use, and on the physical condition of the land, this level of added value corresponds with farm sizes ranging from 2 to 6 ha.

Because of present skills of the prospective farmer-settlers, projected management levels in the LUT's are low to intermediate, including family labour, predominant use of simple farming tools and limited use of fertilizers, agricultural chemicals, etc. Farm labour requirements should not exceed 250- 270 man-days (md) per year. Output levels (yields) assumed in the LUT's are, consequent to the above, not high. They were based on information from the Ministry of Agriculture (Weir, 1974, and personal communication) on guidelines for agricultural credit officers (Jamaican Development Bank, 1977) and on results of agronomic experiments in the vicinity of the area on Orthoxic Palehumults (De Boer, 1981).

In the following, a summary is given of the specific assumptions for the three selected LUT's. The productivity of each LUT is also calculated. These calculations are made for fully developed farms.

Dt: Traditional family-operated dairy farming

Milk production on pastures is the main objective of this LUT. Additional income is generated however, from the sale of young stock and old cows. Houses are on farms, have farm road access, piped water and electricity. Basic assumptions underlying the calculation of productivity include: grazing density (one animal unit consisting of a cow plus calf per 0.8 ha), number of milkings daily (one only), milk production (1590 l per cow per year), pasture management (rotational grazing, bush cutting, fertilizing), use of additional cow feed (concentrates), animal sprays (disinfectants, detergents) and labour requirements (55 md/ha/yr).

Based on the assumptions and on actual prices of October 1978, the date on which this LUT was conceived, the output per hectare (revenue from milk, young stock and old cows) was calculated to be J$ 1375 per year. The cost of the non-factor inputs (concentrates, fertilizers, other expendables) amounted to J$ 340 per hectare per year. Therefore, the added value for this LUT, on land without physical limitations to this use, is J$ 1375—340 or J$ 1035 per hectare per year. Adjusted to the price levels of February 1977 this gives an added value of J$ 870/ha/yr. Therefore, in order to obtain the target farm-added value, a minimum size of 3200 ÷ 870 or 3.7 ha would be required for farms in this LUT. Total labour requirement would then be 204 man-days per year (md/yr).

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Oc: Family-operated citrus orchard farming

In this land utilization type, ortaniques, sweet oranges and grapefruits are produced. Farm houses will be located in a little village at a distance of 700 m from the orchard. The houses are accessible by road and have piped water and electricity. Production assumptions include: tree density (267 trees per hectare), tree lifetime (40 years), replanting (on average 7 trees/ha/yr), yield (350 boxes/ha/yr), use of fertilizers and lime, pest control (fiddler beetle, slugs), and labour requirements (100 md/ha/yr).

According to price levels of March 1979, production under these assumptions would give an output value per hectare of J$ 2620 annually with non-factor costs of J$ 620 per ha/yr. Thus, the added value of produce is J$ 2000/ha/yr, or, if adjusted to price levels of February 1977, J$ 1600. A minimum farm size of 3200 ÷ 1600 or 2 ha of land without physical limitations would be needed to provide the target farm-added value. Total labour requirement on such a farm would be 200 man-days per year.

Gr: Family-operated rainfed garden crop farming

This land utilization type describes crop production in backyard gardens. The proximity of the backyard garden to the farm house and the small area of the garden allow for a relatively high management level in terms of labour input, fertilizer use and application of agricultural chemicals. Basic assumptions of this land utilization type are concerned with:

- choice of crops (yam, red beans, sweet pepper, tomato, pumpkin, cucumber, callaloo, all of which are commonly grown in the area. They represent a range of crops with different cultivation requirements and different economic risks. Yams, for example, are relatively easy to grow and have a stable market. Tomatoes on the other hand are vulnerable and they have an unstable market);
- crop yields (yams 14,000 kg/ha, red beans 550 kg/ha, sweet peppers 8500 kg/ha, tomatoes 6750 kg/ha, pumpkins 6750 kg/ha, cucumbers 5500 kg/ha, and callalooes 6750 kg/ha);
- individual crop area (yam will occupy 1/3 of the garden area, red beans and sweet pepper cover 1/6 of the area each, whereas cucumber, pumpkin, tomato and callaloo each make up 1/12 of the garden);
- cropping intensity (two crops of red beans and callalooes are grown per cropping season; all other crops are grown once per year only);
- use of fertilizers and chemicals (determined for each crop individually);
- application of lime;
- labour requirement (170 md/ha/yr; ploughing with small hired tractor).

At price levels of March 1979 production from this LUT would give an output value of J$ 3875/ha/yr, with non-factor cost totailing J$ 1100. Added value would then be J$ 2775/ha/yr. Adjusted to February 1977 price levels, this is equal to J$ 2220. A complete farm under this land utilization type

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would have a minimum size of 3200 ÷ 2230 or 1.4 ha of land without physical limitations to this use in order to generate the target farm-added value. This would require a labour input of 240 man-days annually.

Diagnostic land characteristics

Study of the soil survey data of the Burnt Ground area in relation to the requirements of the three selected LUT's resulted in the identification of a number of land characteristics with diagnostic significance to land capability due to their direct limiting influences on agricultural productivity. Most of these diagnostic land characteristics, referred to as limitations (and symbolized by lower case letters) in the land capability assessment, could be quantified by measurements in the office, field and laboratory. They are:

- Slope (limitation "e") affecting susceptibility to erosion The subdivision in slope phases is derived from the Soil Conservation Service in Jamaica (Sheng and Stennett, 1975) and has practical significance in soil conservation treatments, e.g. for annual crops involving a large degree of soil disturbance, there is no need for permanent structures on slopes less than 7° (12%), mechanical construction of bench terraces is possible on slopes between 7° and 20° (12—36%), manual construction of bench terraces is possible on slopes between 20° and 25° (36—47%), whereas production of annual crops on slopes steeper than 25° (47%) is inadvisable.
- Effective soil depth or depth to hard bedrock impenetrable to roots (limitation "d") influencing rooting space and availability of moisture and nutrients. Effective soil depth co-determines the feasibility of conservation work, e.g. soil depth on a slope of 20° (36%) must be at least 67 cm to permit building of bench terraces of 2.5 m width (Sheng and Stennett, 1975).
- Stoniness (limitation "s") restricting availability of moisture and nutrients (by taking up effective soil volume) as well as soil workability. The adverse effects of stoniness can be diminished by stone picking and incorporation of stones into stonewalls and stone barriers.
- Rock outcrops (limitation "r") restricting effective soil surface and land management.
- Flooding (limitation "f") adversely affecting crop and pasture performance through physical damage and lack of oxygen.
- Soil acidity (limitation "a") adversely affecting soil fertility through one or more of the following: low effective CEC and related deficiency of bases through presence of clays with variable charges (kaolinite, goethite, haematite and gibbsite), aluminium and manganese toxicity and related phosphorus fixation.

Quantitative land capability assessment per LUT

In the assessment of land capability for the area of Burnt Ground the diagnostic land characteristics (limitations) were quantified relative to the three

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selected LUT's because some of the land characteristics have dissimilar effects on agricultural productivity in different LUT's (Table IV).

For each LUT six land capability classes (symbolized by Roman numerals I through VI) were distinguished according to the degree of the limitations and their effect on productivity. (A range of six classes was adopted following the practice of earlier soil survey interpretations in Jamaica which grouped land qualitatively into six capability classes for general agricultural use.) The effects of the various limitations on productivity in each LUT have been estimated on the basis of area-specific data (De Boer, 1981; Sheng and

TABLE IV

Land capability classes, productivity ratings and limitations for Dt: traditional family-operated dairy farming; Oc: family-operated citrus orchard farming; Gr: family-operated rain-fed garden crop farming

Land capab. class		Productivity (PU/ha)	Productivity (% of max.)	Slope (e) (degrees)	Effect. soil depth (d) (cm)*1	Stoniness (s) (%)*2	Rock outcrop (r) (%)*3	Flooding classes*4 (f)	Soil acidity (a) (pH)*5
Dt	I	8.7	100	0—20	>50	0—15	0—5	0—4	4.5—8.0
Dt	II	7.8	90	20—25	25—50	15—35	5—15	5	n.a.
Dt	III	7.0	80	25—30	n.a.	35—50	15—25	6	n.a.
Dt	IV	6.1	70	n.a.	n.a.	50—75	25—35	n.a.	4.0—4.5
Dt	V	5.2	60	n.a.	n.a.	n.a.	35—45	n.a.	n.a.
Dt	VI	—*6	<50	>30	<25	>75	>45	7	<4.0
Oc	I	16.0	100	0—20	>100	0—15	0—5	0—2	5.5—8.0
Oc	II	14.4	90	20—25	50—100	15—35	5—15	3	5.0—5.5
Oc	III	12.8	80	25—30	25—50	35—50	15—25	4	4.5—5.0
Oc	IV	11.2	70	n.a.	n.a.	50—75	25—35	n.a.	4.0—4.5
Oc	V	9.6	60	n.a.	n.a.	n.a.	35—45	n.a.	n.a.
Oc	VI	—*6	<50	>30	<25	>75	>45	5—7	<4.0
Gr	I	22.2	100	0—7	>100	0—15	0—5	0—1	5.5—8.0
Gr	II	20.0	90	7—15	50—100	15—35	5—15	2	5.0—5.5
Gr	III	17.8	80	15—20	25—50	35—50	15—25	3	4.5—5.0
Gr	IV	15.5	70	20—25	n.a.	n.a.	25—35	n.a.	4.0—4.5
Gr	V	13.3	60	n.a.	n.a.	n.a.	n.a.	n.a.	n.a.
Gr	VI	—*6	<50	>25	<25	>50	>35	4—7	<4.0

n.a. = not applicable.

*1 Depth to hard rock impenetrable to roots.

*2 Stoniness expressed in weighted average of volume percent of coarse fraction in the upper 50 cm of the soil or to hard bedrock if shallower than 50 cm. The coarse fraction includes all particles with diameter larger than 2 mm.

*3 Rock outcrop expressed as percent of surface area.

*4 Flooding is defined as submergence at least 20 cm deep for a period more than one day. The following flooding classes were distinguished.

Class 0: no flooding.

Class 1: one or less floods of one to two days per two years.

Class 2: one or less floods of one to two days per year.

Class 3: one to two floods of one to two days per year.

Class 4: one or less floods of two to four days per year, or three to four floods of one to two days per year.

Class 5: one or less floods of four to ten days per year or ten to twenty cumulative days of flooding per year.

Class 6: one to two floods of four to ten days per year or twenty to thirty cumulative days of flooding per year.

Class 7: flooding conditions exceed those of class 6.

*5 Soil acidity expressed as weighted average of pH (H_2O) 1:1 air dried in the upper 50 cm of soil.

*6 No productivity unit is assigned to class VI.

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Stennett, 1975; Weir, 1974) and general information (Soil Survey Staff, 1975; Sanchez, 1976).

Individual land capability classes were assigned "Productivity Units (PU)" which decrease proportionally from a maximum of 100% for Class I to less than 50% for Class VI. (Absolute values of PU were expressed in Jamaican dollars of added value per year, at price levels of February 1977: 1 PU is J$ 100).

Land capability class I: no limitation to the envisaged use, productivity 100—91% of the calculated maximum.

Land capability class II: slight limitation to the envisaged use, productivity 90—81% of the calculated maximum.

Land capability class III: moderate limitation(s) to the envisaged use, productivity 80—71% of the calculated maximum.

Land capability class IV: severe limitation(s) to the envisaged use, productivity 70—61% of the calculated maximum.

Land capability class V: very severe limitation(s) to the envisaged use, productivity 60—51% of the calculated maximum.

Land capability class VI: extreme limitation(s) which preclude(s) the economic use of such land under the envisaged use, productivity 50% or less of the calculated maximum.

Land capability classes were subdivided into subclasses according to kinds of limitations: e, d, s, r, f and a.

Land capability formulas were assigned to the units of the soil map to provide a land capability map (Fig. 5). The formulas are composed of the following elements in order of placement: (1) a symbol for the LUT consisting of a capital and a small letter, i.e. Dt, Oc, Gr; (2) a symbol for the land capability class, i.e. Roman numerals I through VI; (3) one or more lower case letter(s) symbolizing the limitation(s) in the land capability classes, i.e. e, d, s, r, f, a.

The following formula compositions were used:

(a) Land capability classes I have no limitations; formulas include only symbols for the LUT followed by Roman numeral I, i.e. Dt I, Oc I, Gr I.

(b) Land capability classes II have only one limitation, e.g. Dt IIs.

(c) Land capability classes III through VI may either have one limitation, e.g., Dt III f, or a combination of a major limitation and one or more minor limitation(s) which are shown in brackets, e.g., Oc VI f (a), or a combination of two or more equally intensive limitations, e.g. Gr III e/a. In the last example, "e" and "a" are both Class II limitations but their combination results in placement at Class III level.

APPLICATION OF THE RESULTS

In the preparation of the physical development plan for the Burnt Ground settlement scheme, the land capability assessment played an important part (Fig. 6). It showed that the larger part of the land on the steeply sloping lime-

stone hills in the northern portion of the area, as well as scattered small tracts of land around large sinkholes, have limitations (slope, soil stoniness, rockiness) that preclude their commercial use for any of the three selected LUT's. Hence, it was proposed that these parts of the settlement scheme be in forest. The flood plain of the major waterway crossing the western section of the settlement scheme has a severe flooding limitation rendering the flood plain unsuited for citrus and garden crops. The degree of the flooding limitation still allows use of the flood plain for pasture. Therefore, the development plan proposed that this area be divided among several dairy farms. Related farm houses and backyard gardens of these dairy farms were planned outside the flood plain on the undulating sections of the limestone plateau (Fig. 6).

In the subdivision of all remaining lands (the undulating and rolling limestone plateau) that appeared to be suitable for commercial use under any of the three LUT's, the results of the land capability assessment assisted in the design of the two farm types proposed in the plan, each capable of producing the target farm-added value of J$ 3200 (Febr. 1977). These two farm types are combinations of the LUT's dairy farming (Dt) plus garden cropping (Gr) and citrus farming (Oc) plus garden cropping (Gr), respectively. They are: (1) farm-type 1: traditional dairy smallholdings (3.4—4.0 ha) with garden crop farming (0.14 ha) as a minor component (Fig. 6); (2) farm-type 2: traditional citrus smallholdings (1.8—1.9 ha) with garden crop farming (0.14 ha) as a minor component.

This resulted in the delineation of 128 farms of type 1 and 14 farms of type 2.

CONCLUSIONS

The example of land use planning described in this article shows the central place that soil information takes in the execution of quantitative land capability assessment for rural development planning.

The method of land capability assessment which was applied in Jamaica along lines related to the Land Evaluation approach (Beek and Bennema, 1971; FAO, 1976; Beek, 1978) matches the requirements of certain well-defined kinds of land use (land utilization types) with physical land attributes. The assessment provides a quantified basis for the delineation of farms, each capable of producing a target farm income, in detailed development planning.

The LUT's defined in Jamaica were patterned after the checklist prepared by Beek (1978, pp. 48—51) but were simplified. Also, for the characterization of physical land conditions, land characteristics were used instead of land qualities. Land characteristics, single attributes of land, can be measured directly (e.g. slope, soil depth, etc.), whereas land qualities are complex attributes of land, the expression of which is determined by a set of interacting single or compound land characteristics (e.g. moisture availability, erodibility, etc.). Moreover, the use of land characteristics has the practical advantage that the grouping of land capability classes and sub-classes according to diagnostic

characteristics relevant to the various LUT's can be based directly on the soil map. The soil map units are described in terms of, and differentiate between, land characteristics. Another advantage of the use of land characteristics instead of land qualities is that the quantification of their relationships with the requirements of the LUT's and their effects on productivity is a somewhat easier process. Nevertheless, this matching process remains the weakest link in the land evaluation approach. In particular, this is a problem in the developing countries, where research data and farm records are often limited. Therefore, by necessity these relations have to be based largely on assumptions. In the making of these assumptions it is in the direct interest of the farmer-settlers that they do not overestimate productivity.

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