

Land evaluation by physiographic analysis in the Savanna belt of Western Nigeria

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Abstract

A study of land evaluation in connection with agricultural development was carried out in the Iganna area, north west of Oyo, Nigeria. By mapping the area into physiographic units which are fully characterised, a very simple categorisation of the land units into capability classes was made. Factors considered in the grouping include soil, topographic and climatic factors and land use pattern. Most of these factors were fully described or indexed in the course of the survey while the data on the rest were collected from literature.

It was found that physiographic analysis adequately mapped the area into units of similar soil characteristics. The factors which are considered very important to land use in the area are also very similar within the mapping units. Thus, a capability grouping based on this basic information is found to have a high degree of credibility.

Under the prevailing economic conditions and the urgency for a speedy development of agricultural potentials in developing countries, there seems to be no cheaper, more rapid and yet much more reliable method of evaluating agricultural potentials than this method.

Introduction

Before carrying out an agricultural development project, it is very essential to have the necessary basic information about the land on which such a project is about to be sited. This is particularly true for an underdeveloped country where basic soil information and agronomic experiences are limited.

The Iganna Estate is a typical example of a land in an underdeveloped country. There are no soil survey reports but geological and topographical maps and the aerial photographs of the area are available

The system of agriculture is shifting cultivation and only a very small fraction of the land under investigation was being cultivated at the time of this study.

This exercise of mapping the Iganna Estate and of assessing the land use potential for agricultural purposes Provides a good example of how such a project can be handled under conditions prevailing in a developing country. Owing to the urgency of the information required and the paucity of suitable references, a great deal of relevant data were obtained in the course of the soil survey.

Land resources surveys such as the one under consideration is usually approached from an integrated angle. This means that scientists in various disciplines work together as a team to produce a comprehensive report for the development project envisaged. An outline of procedures to follow in such an exercise is given by Buringh (1962). Doeko Goosen (1964) and Francis (1968). A similar project was discussed for Chile by Quinn (1968). In all these Projects team work is stressed.

The success of the exercise depends very much on the use of aerial photo interpretation techniques for the collection of the scientific data required for the subsequent planning and recommendation. Usually, a large area has to be surveyed within a relatively short time. By a judicious elimination of non-promising areas and the selection of the more promising areas for more detailed survey, the time required to complete such a survey may be reduced to as low as 10% of the normal time.

A fairly well established method of carrying out this type of survey has been in use in Australia for about forty years. It consists in the analysis of the landscape into *land systems* (Christian, 1958; Christian and Stewart, 1947, 1953, 1968).

A land system is a unit of mapping for large, geographical areas. It is composed of smaller lanscape units which are associated with one another in a particular way and this association of units are recurrent for any geographical area of the same land system. A land system is usually characterized by the same geology, climate and geomorphic history. Where changes in any of these attributes are sufficiently drastic, a new land system begins.

For projects other than land resources development, this method of landscape or physiographic analysis has been extensively used by the British (Webster, 1965; Mitchell, 1968). They have also used it for making land Resources inventories (Collier et al, 1968; Bawden, 1968; Bawden and Langdele-Brown, 1968; and more recently by Murdoch et al (1976).

Physiographic analysis consists in the selection of criteria for identifying and recognizing physiographic units or land facets on aerial photographs. The procedures for physiographic analysis were enunciated by Webster (1965) and Fagbami (1972) and applied to parts of Nigeria by Bennett et

al (1979) and Fagbami (1980). After establishing the mapping units, the task of mapping the units from aerial photographs becomes much easier — since similar units make similar patterns on aerial photographs.

Land is usually regarded as a composite of regional climate, microclimate, soil, land form characteristics, flora, fauna and water. In evaluating the agricultural value of a piece of land, all these factors of the ecosystem need be taken into account before arriving at any conclusions. A full description and mapping of the soils are a pre-requisite in any land potential assessment as enunciated by Klingebiel and Montgonery (1961) but land capability classification may be done without first mapping the soils as done for the Mambilla Plateau (LIDECO, 1978). For conventional mapping, soil series is described as the unit of mapping. However, the idea of using physiographic units is to fully characterise the ecosystem by describing these units, each of which is a composite of factors of the ecosystem. A fairly high degree of uniformity of these factors is assumed within each of the units. This assumption is fully justified by the works of Webster (1965), Michell (1968) and Fagbami, (1972) who found a fairly high degree of homogeneity within physiographic mapping units, each of which can be used over its whole extent for the same type of land use, and more recently in Nigeria by the work of Areola (1982) and Fagbami and Vega-catalan (1980), that is, their land use potential is the same.

The mapping of physiographic units is easier and cheaper than soil series mapping and a land evaluation exercise based on a carefully done physiographic mapping has a high credibility, especially if it is limited to giving indications of capability rather than predicting crop yield. This is because a reliable prediction of the yield of a particular crop on a particular type of soil will require many years of agronomic experimentation and yield data collection. Data and results from similar climatic zones especially if near the area of investigation may be useful in making rough predictions of yield if similar management practices are adopted for specific type of crops, although limitations of such a procedure should be borne in mind. For instance, interactions of ecological factors vary from locality to locality, no matter how similar climatic characteristics may be.

Materials and Methods

Location and Physiography

The estate which measures about 104 km² is located within the Southern Guinea Savanna about 80km north west of Oyo

The land forms are dominated by gently inclined pediments with a few residual hills. Rivers are incised into the pediments in a fairly thick network, Fig. 1. All the streams show evidence of rejuvenation as is illustrated by the rapidity of flow and the narrowness of the alluvial deposits. The pediments seldom rise about 1° within the first few hundred meters of the river valleys but become steeper farther away from the valleys.

The predominant landscape features of this area are the gentle relief of the pediments, the occasional residuals (otherwise known as inselbergs), ruwares (ground-level low residuals) and the rejuvenated Valleys.

Geology, Climate and Vegetation

The area is underlain by the Basement Complex of Pre-Cambrian age which forms most of the substructure of the African landscape. The vegetation of the area is predominantly savanna with a few small pockets of forest. The rainfall is characterically much lower than that of the southern forest belt. The agricultural practices are synchronised with the alternating nature of the climate. Most of the crops grown in the area are annual and for most of the dry season the land is rested. Mechanisation is little known to the people and the only mechanization practised is in the production of tobacco.

Method of Survey

The procedures followed in the survey of the Iganna Estate is outlined below:

1. *Preliminary Photo Interpretation:*

The photographs used were those taken by the Canadian Aero Service Ltd. in 1964. The scale of the photographs is 1:40,000. The photographs were studied and tentative land facets identified.

2. *Ground reconnaissance:*

The estate was reconnoitred along the motorable roads, for two days. The idea was to see the relationship between field features and photo patterns. This exercise was designed to lead on the soil surveyor to modify or confirm the tentative land facets as mapping units. Relationships among the facets and the variation of features within them are best observed in the field so that when photo-mapping is to be undertaken the exercise will be less tedious and more reliable.

3. *Full Photo Interpretation:*

The area was photo-mapped after the second stage of the exercise. Sample areas for ground mapping were demarcated on the aerial photographs and on the topographic base maps. The sample areas were selected in such a way that all the landscape features and environmental conditions within them (the sample areas) can be investigated and they need to be easily accessible.

4. *Ground work:*

Ground examination was carried out by traversing the sample areas on traces. The bearings of the traces were predetermined. An arbitrary spacing of 635m (2,100 ft.) of traces within each sample area was chosen. This assumes that within a distance of 320 m (1,050 ft.) on either side of each trace, soil properties would be fairly uniform. This is a reasonable assumption as soil properties do not change rapidly and are fairly similar over wide areas. The traces were placed such that they cut across rather than run along the contour.

Initially three traces were cut in each sample area at a fixed length of 75 chains. After the first two sample areas were completed, modifications were introduced in order to:

- (i) accommodate the sampling of all the geological types,
- (ii) reach areas inaccessible by the Land Rover (For such an area unusually long traverses were cut from a road station to a point where necessary samplings and examinations could be carried out and
- (iii) select alternative sample areas where accessibility was not possible because permission was not granted.

Profiles were sited in areas sufficiently representative of the facets by auger examination. This precludes profile examination at regular intervals, ostensibly because the facets themselves are not uniformly distributed. The profiles were described using the USDA (1951) standard description. Soil samples (for chemical analysis) were collected at each horizon by taking chips throughout the length and breadth of the horizon. A special surface 0–15 cm sample was also taken.

5. *Adjustment of aerial photo interpretation and final facet description:*

About half way through the ground work, another round of full photo interpretation was done to make necessary adjustments to the facet mapping in the light of observations made on the ground. It was not found necessary after this operation to do any further readjustment in the definition of the facets but minor readjustments were made to the boundaries.

Four facets were described for the area: facets F1, F2, F4 and F5. Facet 2, the pediment slopes, was subdivided into sub-facets on the basis of the position on the landscape; top slope – F2 (1), middle slope – F2(2), lower slope – F2(3), and the break of slope – F2(4).

Results and Discussions:

The associations of these facets with one another is consistent throughout the whole area and they are therefore found recurring over and over again. The association of sub-facets within facet 2 is illustrated in fig. 2. The characteristics of the land facets and sub-facets which constitute the Iganna land system are summarized in Table 1.

The Assessment of Land Use Potential

Factors affecting land use in the Iganna area:

The following factors have been considered the most likely to affect the capability of the land in this area even though it is difficult to trace the effect of the different factors on yield levels at this stage and hence attribute "values" to the factors. This is because the soil management level of this area is primitive and records of yield were not kept by the farmers.

1. *Topographic Factors:*

a. *Slope:* From observations made so far, it seems that except in the very level ground, erosion is active on all sloping surfaces. A few areas have steep slopes that may constitute some hazard to mechanization but under the present level of management, only the erosional aspect calls for concern. On extensive flat land, there is a tendency towards the formation of ironstone (laterite) crust within the rooting zone owing to fluctuation of water table caused by little or no lateral movement of water within the soil.

b. *Position in the landscape:* The position in the landscape may be a more important factor of land use than the absolute degree of slope. Even though erosion is very active on all slope surface the relative position of the slopes will determine the intensity and degree of devastation by erosion. For example, top slopes are far more susceptible to erosion. Besides, some of the materials washed down from the top slopes are deposited on these lower positions thus contributing to the agricultural quality of the lands in such positions.

The position in the landscape also determines the level of moisture in the soil mass.

Table 1: Iganna Land System

	Approximate % of total	Position in the landscape	Surficial deposits	Slope, shape and relief	Important Soil Characteristics	Present land use	Vegetation	Land use potential
F1 Hill Crescent.	%	At the Crests of hills Elevation: 183m - 244m	Mainly derived in situ. Rock outcrops may be present	Slope varies from 1° - 5° Slightly convex	A few show characteristics of skeletal soils. Soils devoid of concretionary materials, dark-stained in top horizon. Quantity of stones depend on nature of country rocks. Being actively eroded. Parent rock usually encountered between 80 cm - 100 cm.	Mainly grazed, but some arable cultivation.	<i>Fimbristylis hispida</i> , <i>Borreria</i> sp. and <i>Euphorbia hirta</i> appear typical.	Erosion and rock-outcropping reduce the capability of the unit. Some will support arable cropping but would better be used for grazing.
Pediment slopes: about 80% F2(1) (Top Slope)	10%	Located in the upper part of the pediment slopes. Elevation 175a-228a.	Mainly in situ.	Varies from flat to slightly convex, slope varies from less than 1° to 5°	A mixture of Latosols (Charter, 1957) and Sols Ferrugineux Tropicaux (Aubert, 1962). Fairly free of concretionary iron crust. Weathered parent rock encountered in about 50% of the profiles and about 50% also contain quartzite gravels. Depth to weathered mass is 80-100cm; depth to indurated or partially indurated crust varies with the angle of slope.	Extensively used for arable cropping. It is also used for grazing. In remote areas it is not used at all.	Cultivation introduces new species such as <i>Imperata cylindrica</i> , <i>Indigofera</i> sp., <i>D. velutina</i> , <i>Tidax procumbens</i> , <i>Borreria</i> sp.	Most of it can be developed for arable cropping but should not be cultivated for too long because of the danger of erosion (It is an area of active denudation).
F2(2) (middle slope)	40%	Located just below F2(1) Elevation ranges from 168m to 229m.	Top stoneless horizon of transported material. Below material is in situ.		More concretions or concretionary iron crust is encountered than in the adjacent F2(1). Parent materials encountered in less than 25% of the profiles, so that profiles are deeper than in F2(1).			There is erosion of material away from here but there is also deposition taking place. Agricultural potential is moderate to high, the main limitation being low precipitation for most of the year.
F2(3) (Lower slope)	25%	Located next to F2(2) on the valley end of slope. Very few occurrences above 200m. Range: 175m - 213m.	Similar to F2(2) but the transported top layer is thicker than in F2(2).	Slope varies from nearly flat to gentle convex. 1° - 6°	Depth to indurated or partially indurated layer is F2(2) but the frequency is similar. Weathered parent rock encountered in less than 20% of the occurrence examined. Clay mottling			Potential is a little higher than that of adjacent F2(2) because of additional moisture factor. F2(3) is averagely more moist than F2(2).

Table 1 Contd

	Approximate % of total	Position in the landscape	Surficial deposits	Slope, shape and relief	Important Soil Characteristics	Present land use	Vegetation	Land use potential
F2(4) (Concretionary shoulder)	5%	Narrow strip immediately above the river alluvium. A point of considerable water table fluctuation.	Either in form of concretionary gravels and boulders or more commonly ironstone crust.	Slope is markedly convex: varies from 1.5° - 7°	Thin, concretion-free top horizon, overlying the concretionary crust. Water tension is likely to be high in the dry season as the hardens. Depth to concretionary crust is the shallowest in the area. Correspond to the Gambhari series of Smyth and Montgomery. (1962).	Grazing	Fringing forest species quite common.	Had better be avoided as the concretionary crust creates rooting zone obstruction problem.
F4 (Alluvium)	7%	Located along the streams. The lowest-placed facet of the area.	Alluvial sand in most cases but clay alluvium along the main river of the area.	Generally flat with slope less than 1°. hummocky micro-relief.	The sandy deposits have fairly well developed structure in the surface horizon but this deteriorates with depth. The alluvial clays are dominated by massive structure. Usually no stones in profile. Partial indurations in places but well outside rooting zone.	Very little use presently made of the unit.	Fringing forests. Main species: <i>Elaeis guineensis</i> , <i>Cissus</i> sp., <i>Dioscorea</i> sp., <i>Desmodium volu- tina</i> , <i>clematis hyrcana</i> .	Perhaps the unit with the highest untapped potential. Barrage Flood by the rivers, it is probably possible to keep it under cultivation all year round because it is moist even in the dry season.
F5	3%	Located in the head-water regions between hill peaks.	Characterised by thick deposit of fine material washed down from the hill slopes into their present position on top of materials developed in situ.	Saucer-shaped slope varies from 1.5° to 5°	Soils have moderately to well developed structure in top horizon. Texture is generally on the sandy side. 80% of profile examined have no stones. Soils averagely deeper than those of the surrounding soils of the side slopes. Correspond to the hill wash soils of Smyth and Montgomery (1962).	Widely used for arable cropping.	Similar to that of the surrounding facets but usually more lush especially at the undergrowth level.	The unit with the highest potential, moist, all year round and free of flooding that bedevil the F4.

c. *Altitude*: Altitude does not carry the same weight in this area as it does in areas of very high elevation or in high latitude areas where temperature and rainfall variations are very marked along the contour.

2. *Soil Factors*

a. *Soil depth and soil induration*: Depth to indurated layer is one of the most important land use factors as it is crucial to the establishment and survival of crops. Similarly, rooting zone obstructions such as stones or bed-rock are also important.

b. *Gravel concentration and stoniness*: Gravels and stones have a diluting effect on rooting volume of the soil. Abundance of small gravels such as concretions and quartz gravels can also badly affect the soil structure as they tend to impose on the soil a running consistency especially in sandy soils. Furthermore, they make the soil so porous that the water-holding capacity of the soil is considerably reduced.

Gravels do not seriously obstruct root growth, only if climatic conditions change sufficiently (such as by pronounced drought) to lead to the cementation of the gravels. When this happens the gravels harden into a hard crust and impede root development.

c. *Drainage*: Poorly drained soils are very rare in the Iganna estate. These occur mainly along the Ofiki river. Flooding of the alluvial soils during the rainy season is a common feature. Natural drainage may be expected to influence crop yield.

d. *Chemical properties*: Nutrient levels are likely to be low over most of the area which suggest the necessity to use fertilizers to increase crop yield. This is partly because most of the rocks of the area are acidic.

3. *Climatic Factors*

a. *Rainfall*: Rainfall is a limiting factor in the area. The 1180 mm (47") annual rainfall is so unpredictable and so poorly distributed over the year that effective cropping season spans only a few months. (Table 2). Rainfall is perhaps the most crucial factor of land use in this area. This fact emphasises the necessity of developing irrigation schemes for reliable cropping programs.

b. *Radiation and temperature*: There is hardly any variation in these factors over the whole area. The effect on crop yield would therefore be expected to be uniform. They are limiting to land capability as they contribute a great deal to the high, unmeasured evapotranspiration; and together they accelerate the dropping of the crop leaves especially of maize in the

Table 2: TOTAL MONTHLY RAINFALL (mm) FOR THE OKEJHO L.A. SCHOOL (About 15 km. East of the Estate)

Year	JAN.	FEB.	MAR.	APR.	MAY	JUNE	JULY	AUG.	SEPT.	OCT.	NOV.	DEC.	Yearly Total (mm)
1958	22.0	54.5	17.5	155.3	63.8	91.3	3.0	35.5	139.0	147.5	114.0	31.5	874.9
1959	0.0	30.0	106.3	137.8	257.0	167.5	198.5	117.5	192.0	119.3	50.0	0.0	1385.9
1960	0.0	0.0	129.3	95.5	45.5	193.0	158.5	152.5	284.8	189.3	60.0	21.8	1330.5
1962	0.0	0.0	85.8	295.5	209.8	223.8	223.8	223.3	147.0	189.3	149.5	0.0	1807.3
1963	10.0	32.0	70.0	153.8	180.3	252.8	294.0	3392.3	238.8	294.0	7.5	0.0	1925.5
1964	0.0	0.0	53.5	195.8	126.3	172.3	164.3	79.8	191.8	48.0	0.0	32.5	1064.3
1965	0.0	0.0	45.3	24.0	82.5	1107.5	225.8	47.5	118.5	1156.3	9.3	0.0	816.7
1966	0.0	77.8	32.8	75.8	306.3	289.0	62.0	151.3	74.5	189.8	7.0	0.0	1207.3
1967	0.0	0.0	72.3	34.0	71.3	139.8	197.3	143.0	171.8	106.8	16.5	20.3	973.1
1968	0.0	40.0	86.8	234.3	53.8	143.3	493.3	266.8	215.5	144.8	0.5	0.0	1677.1
1969	0.0	0.0	67.8	71.5	214.3	142.0	75.0	169.5	260.5	152.8	19.8	0.0	1173.2
1970	42.0	39.8	11.3	31.3	164.0	195.3	70.0	140.8	55.8	55.8	0.0	0.0	766.3
1971	0.0	25.0	95.8	172.3	154.5	155.5	153.0	125.8	52.8	52.8	0.0	0.0	1081.2
1972	0.0	7.8	109.8	0.0	145.3	106.0	33.5	0.0	59.8	60.5	0.0	0.0	522.7
14-year Total (mm)	74.0	306.9	984.3	1676.9	2084.7	2362.0	2362.0	1934.5	2360.6	1907.0	434.4	106.1	16670
Aver. (mm)	5.3	21.0	70.3	119.8	148.9	174.2	168.7	137.5	168.6	136.2	31.0	7.6	

afternoons during soil water stress.

4. *Land Use Pattern*

a. *Grazing*: In integrated crop and animal farming, grazing should contribute positively to land capability. But in the uncontrolled system of grazing practised in the Iganna area, it tends to impoverish overgrazed areas through trampling and removal of vegetative cover which accelerates erosion.

b. *Burning*: The estate is subjected to annual burning. Burning temporarily arrests biological processes and exposes the whole land surface to insolation and erosion, the effects of which are negative to land capability. Nutrients released by burning are partly lost in run-off water, partly evaporated, and partly washed down the profile, some beyond the reach of roots. Burning also contributes to accelerated erosion.

c. *Cultivation*: Cultivation may affect the capability of land depending on the level of management adopted. Bad management could ruin a piece of land. The land use factors are not permanent factors of land capability and their defects can be removed once and for all.

Grouping of Facets into Capability Classes:

The assessment of the land potentials was made by grouping the land facets into capability classes on the basis of their inherent qualities and the factors of the physical environment discussed in the foregoing section.

Since this is a strictly agricultural development project, it is necessary to adopt a system of land capability grouping which is exclusive to agricultural potentiality. This is slightly different from the agroforestral framework of Klingebiel and Montgomery (1961).

The facets are grouped into five capability class I to V. Class I land is supposed to have only minor limitations. Limitations increase from I to V. However, because of the severe climatic limitation (low and unpredictable rainfall), no land in the area is qualified to be in class I. This grouping, which is based on those factors listed above, is balanced against the grading of the physical and chemical properties of the country rocks. In essence therefore, the capability of a particular facet would be slightly modified by the rating assigned to the geological material on which it is located. (Table 3). This assumes that, the local country rocks still exert some influence on the physical and chemical properties of the soils.

Table 3: FACET CAPABILITY GROUPING CHART

Facets		F5	F2(3)	F2(2)	F4	F2(1)	F1	Fs(4)	
Capability Grading		5	4	4	4	4	2	1	
Lithological Grading	f+h	5	10	9	9	(9)	8	7	6
	d	4	9	8	8	(8)	7	6	5
	g	3	8	7	7	(7)	6	5	4
	e	2	7	6	6	(6)	5	1	3
	b	1	6	5	5	(5)	4	3	2

Grading	Capability Class	Demotion by 1 for Climatic Reasons
9 – 10	1 V. Good	2 Good
7 – 8	2 Good	3 Fairly Good
5 – 6	3 Fairly Good	4 Fair
Below 5	4 Fair	5 Poor

where f = amphibole schists plus amphibolite
h = biotite gneiss plus intercalated amphibolite
d = Pegmatite
g = undifferentiated gneiss complex
e = quartz schist and quartzites
b = Porphyritic biotite granite
() denotes that the relationship of alluvial soils F4, to local geology is negligible.

The grading in each column is obtained by the addition of the ratings on the capability grading to the ratings on lithological class. For example, F5 on pegmatite has a final grading of 9, that is 5 (on capability grading) and 4 (on lithological grading).

In making the above capability grouping the following assumptions have been made:

- i) that a moderately high level of management is going to be adopted as opposed to the present primitive and low level of management practised.
- ii) that even though the classification is not for a specific crop it assumes that grains and some familiar root crops of the area are the principal crops to be grown in the estate.

It should also be noted that this capability grouping is based on the present level of knowledge. As the project gets underway and as more and more is known about the behaviour of the soils of the area under specific types of management, modifications may have to be made in the light of the new knowledge. For example, it may be found that the emphasis placed on lithology in the present scheme may become unnecessary if other factors of the environment are found to exert an overwhelming influence on land potential.

Conclusions

It has been found that physiographic analysis adequately maps the area into units of similar soil characteristics although it remains to be proved statistically that the different units are sufficiently homogenous within themselves and sufficiently different from one another to justify their separation.

Under the prevailing economic conditions and the need for speedy development of agricultural potentials in developing countries there seems to be no cheaper, more rapid and yet much more reliable method of evaluating agricultural potentials than this method just discussed.

It will be worthwhile, to investigate the possibility of using this method in the forested belt of this part of Africa. It may be found that a more thorough ground check is necessary to avoid misinterpretation of features under the thick forest covers.

It is pertinent to suggest that investigations such as this one be quickly followed by agronomic trials for more reliable recommendations.

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