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PROPOSAL FOR A GLOBAL LAND USE CLASSIFICATION

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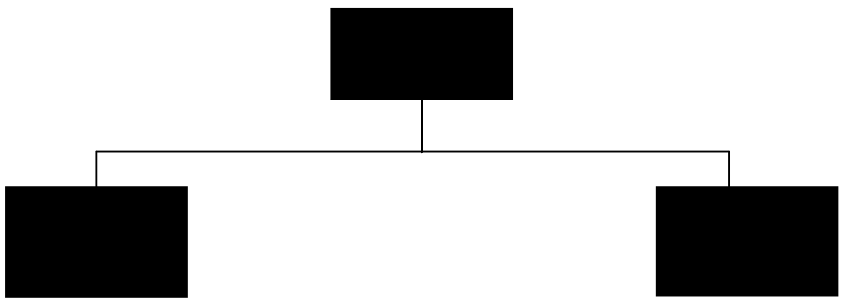

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PREFACE

The following report is the result of a study carried out at the request of the Food and Agriculture Organization of the United Nations (FAO). The proposed concept for a global land use classification is a sequel to the draft *"Describing Agricultural Land Use"* of Stomph & Fresco (1991).

For many reasons, such as the assessment of the effects of land use on environmental degradation, or the interaction of land use and climatic change, as well as for the planned world agricultural census 2000, there is an urgent need to establish internationally recognized standards for the typology and classification of land use. Methods of defining land in terms of climate, topography and soil have been developed over many years. But until now there is no satisfactory and commonly accepted method of defining and classifying land use for the whole world.

In this report land use is classified, in it's operation context, based on the concept of the *operation sequence*, proposed in 'describing agricultural land use' (Stomph & Fresco, 1991). This means that land use is only classified in biophysical terms. Land use includes plant biomass production systems as well as animal biomass production systems, but they are classified separately, while both can occur at the same place. The LUIS (Land Use Information System) Working Group has concentrated so far on the classification of plant biomass production. This can be justified by the fact that biological use of the land always implicates plant biomass production, whether there is animal biomass production or not. So plant biomass production forms the basis for the classification of agricultural land use.

The report discusses the major principles of land use classification and contains a proposal for the first five hierarchical levels of a global land use classification.

One has to realise that the report deals with the classification of land use and not with the classification of land use systems, which is based on the occurrence of specific combinations of land use and land (resources). The classification of land use systems is an other exercise and is until now beyond the intentions of the LUIS Working Group. Also the particular problem of mapping land use is considered as a special exercise and is not discussed in the report.
Proposal for a Global Land Use Classification

The LUIS Working Group was established in August 1992 as a follow-up on earlier collaboration between the involved institutes on the description of land use and the development of a land use data base design (Stomph & Fresco, 1991). The working group started on elaboration of a land use classification and further on the development of the land use database design to record all georeferenced details of land use. Both apply the concept of the operation sequence. The data entry component of the land use database has been developed for crop husbandry (de Bie & van Leeuwen, 1992). As we know, land use is strongly related to socio-economic factors and data on these are needed to support decisions on land use. But only recently the LUIS Working Group has started the conceptual integration of socio-economic data into the land use database design.

The work presented in this report was executed under supervision of the LUIS Working Group and their inputs are gratefully acknowledged.

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1 PURPOSE OF LAND USE CLASSIFICATION

1.1 Overview of land use surveys and related classifications

" The Problem of utilization of land by Man and its consequences has interested people from time immemorial. As a result some kind of inventories were carried out in ancient Egypt, Mesopotamia and China in quite remote epochs and continued in the Roman period. In the medieval times the Domesday Book of Britain, dated from the end of the eleventh century, was analyzed in great detail. The cadaster survey carried out in various European countries in the eighteenth and nineteenth centuries provided detailed material that has been analyzed by numerous geographers up to the present day. However the memorable Land Utilization Survey of Britain should be considered the first one that covered an extensive area in a comprehensive and comparative way" (Kostrowicki, 1983).

In the late sixties the interest in land use surveys declined, because of criticism of the static character and labour absorbing methods of the survey based on field work. The newly introduced techniques, such as aerial photographs and satellite images, have made field work "unnecessary", and since such surveys could be repeated several times it could impart a more dynamic character **to** them, too. New classifications of 'land use' forms were elaborated and adapted to what could be interpreted from air and satellite photographs. These new classifications are based on land cover, rather than on land use. With the exception of the Polish method little attempt has been made to explain by whom and in which way land has actually been used, what was the intensity of the land use, its functioning, effectiveness, etc., i.e. to approach land use problems in a comprehensive way (Kostrowicki, 1983). As is shown below many 'land use' classifications have been introduced, but none of these is acceptable and satisfactory as a method of defining and classifying land use for the whole world.

1.2 Examples of drawbacks of existing classifications

All reviewed 'land use' classifications suffer from one or more of the following drawbacks (Mücher, 1992):

1. The lack of a sound definition of the units of analysis: these may range from field to farm to region, and are too often confused with the mapping unit.

2. Overlapping land use classes, because of no or unclear defined criteria. Most hierarchical classifications are only comprehensive, for their scope of interest at the first hierarchical level, but are far from comprehensive at lower hierarchical levels.

3. The nearly ubiquitous absence of quantitative class boundaries (critical or threshold values of the criteria) making an assignment of land use to a specific class rather subjective.

4. The combination of land use with other features such as climate characteristics that may influence land use but are not inherent features of land use.

5. The multitude of objectives of land use classification often closely tied to regional or disciplinary focus.

1.3 The need for a unified classification system on land use

Classification systems depend on the purpose of the classification. In the past, many authors of land use classification had different purposes and the result was an amalgam of classification methods to describe land use. As a result, today, comparison across time and space of land use has become very arduous. There is no agreement on any of the common classificatory principles. So, the need for a unified and effective land use classification system for the comparison of land use across time and space, which can be used for a broad range of policy, land use planning and statistics, is widely recognized. Especially, the higher hierarchical levels of global land use classification need to be unified and accepted worldwide. At levels of greater detail there can be flexibility to include land rise classes that depend on the choice of the region and the purpose of a study. However, these land use classes also need quantitative class boundaries to make some comparability possible.

Just like in other sciences, a unified classification system, based on observable criteria, is essential to encourage the transfer of information between researchers, agronomists, land use planners, land evaluators and professionals interested in related issues such as global environmental changes and sustainable agriculture. The last issue in particular calls for a much better understanding of how land is used and how land use has changed and may change and how land use can be influenced. Also the availability of modem information technology, allowing the disaggregated storage of large quantities of complex data, forms the basis of - and at the same time calls for - some system of classification.
To realize a consistent and comprehensive classification on land use for the whole world it is necessary that the classification comprises the following features.

1.4 The features of a sound and universally applicable classification

1. The land use classification must be comprehensive.

2. The criteria must be based on inherent characteristics of the land use. So, the land use classification will have as only object land use. In this way the land use classification will be complementary to other classifications, for example soil classification, vegetation classification and farming systems classification, yet all of these should be independent. (Of course, the legend of, for example, a landscape ecology map can be a combination of landform, vegetation and land use, for which the classes are derived from the different classifications).

3. The <u>determining factors</u> or diagnostic criteria for the classification of land use should be <u>as stable as</u> possible, meaning that they are characteristic for the land use over a longer time period (e.g. burning is one of the determining characteristics of shifting cultivation, although the action takes place in a few hours or in a few days).

4. The <u>basic unit of analysis</u>, as the unit of observation, will be the *'unit of biophysical management"*[1]. For forestry, livestock production systems, and fishery the term fleld\parcel\plot (see Glossary) is not useful. The term 'unit of biophysical management' is the only useful term for the basic unit of analysis, because it is the only term that can be applied to all land use. Still the 'unit of biophysical management' for arable cropping is the plot.

5. The <u>diagnostic criteria</u>, independent of the hierarchical level in the classification, will be differentiating characteristics at the 'field' level. This approach is similar to the use of diagnostic

horizons in soil classification. However, some biophysical characteristics of the land use like infrastructure and irrigation are not implemented at the plot level, but are implemented at a higher level. As an exception infrastructure and irrigation will be expressed as characteristics of each of the 'units of biophysical management' for which they are relevant.

6. Contrary to the basic unit of analysis (e.g. plot), which is scale dependent, the land use classification as such will be scale independent; meaning that the classes of the highest hierarchical level in the land use classification, and the classes of lower hierarchical levels should be applicable at any scale or level of detail.

7. The land use classification is a multi-categorical system, with only a few diagnostic criteria at the highest level of the hierarchy and a restricted number of classes. With a decreasing level in the hierarchy the number of diagnostic criteria increases together with the number of classes. Diagnostic criteria at one level of the hierarchy of the land use classification should not be used again at a lower level of the hierarchy as diagnostic criteria.

8. The approach for a land use classification should be as pragmatic as possible (within limits set by the concept). The main users of the land use classification will be policy makers of international organizations, policy makers in national organizations, land use planners, and scientists. They will be working on a global/continental scale, at a national scale or at a regional scale. The hierarchical levels of the land use classification should be convenient for the user, and should be applied easily by any of the above mentioned groups.

9. The land use classification should have a logical and scientifically sound foundation. The Soil Taxonomy and FAO soil classification are strongly related **to** the general principles of soil genesis, i.e. based on "pedogenetic" principles. The sets of quantitatively defined properties, produced by soil forming processes, have made it possible to base the (guiding principles of) classification on the principles of soil genesis. Similarly, biological taxonomies are "phylogenetic" i.e. based on the evolution of species. In order to fully reflect the dynamics of land use, the land use classification should be related to the evolution of land use, in one word: **'usugenetic'.**

[1] A "unit of biophysical management" is defined here as a fixed area, which is manipulated by the user through a particular sequence of operations over several years. Note that in this context "unit of biophysical management" is on the level of the (biophysical) land use unit and not on the level of farming systems.

2 UNDERSTANDING LAND USE

2.1 Land use versus land cover

Many existing land use classifications are based on *land cover*, defined as the vegetational and artificial constructions covering the land surface, including waterbodies. Examples of land cover classifications are (Scace, 1981): The World Land Use Classification, The Canada Land Inventory and Land Use Classification, the Second Land Use Survey of Britain Classification and the Canadian Land Use Classification, with mapping information at a scale of respectively: 9 categories at 1:1,000,000; 6 categories at 1:250,000; 13 categories at 1:25,000; 7 categories at 1:1,000,000.

Land cover is the result of land use at a certain moment in time. Land cover can change rapidly and the same piece of land can be classified differently (on land cover) the next year, or even the next day. However, land cover maps are an excellent tool for the analysis of the spatial distribution of land use (at a certain moment in time). A land cover classification is different from a land use classification, but they are related. For example, inputs applied in time, such as which crops are planted or sown, are included in the description of land use and indicate the stages of cover through time. Making it possible to relate land cover to land use. While land cover is determined at one moment, the land use is determined over a longer time period. The relationship between cover and use needs to be established formally - as part of a future exercise.

2.2 Describing agricultural land use

To begin with, there is considerable diversity of opinion about what constitutes *land use*, although present use of land is one of the characteristics that is widely recognized as significant for planning and management purposes. One concept that has much merit is that land use refers to, "man's activities on land which are directly related to the land" (Anderson *et al*., 1976).

From the last paragraph it is clear that what one observes in the field is the land cover and not the land use, because it is the visual result of the land use at a certain moment in time. In the field one can observe the land cover, which can be the natural vegetation, or, as in most cases, the modified natural vegetation after man's interaction on the land.

Contrary to the land cover, land use can only be determined over a certain time period. This time period has to be long enough to determine the sequence of operations, their timing, the applied inputs and the implements and traction source used for the execution of the operations. This framework is used in the concept of the sequence of operation for describing land use, bound to a certain piece of land. Especially, for sustainable agriculture it is significant to approach land use in its operation context, because changes towards more sustainable land use imply changes in operations, their timing and associated inputs and implements.

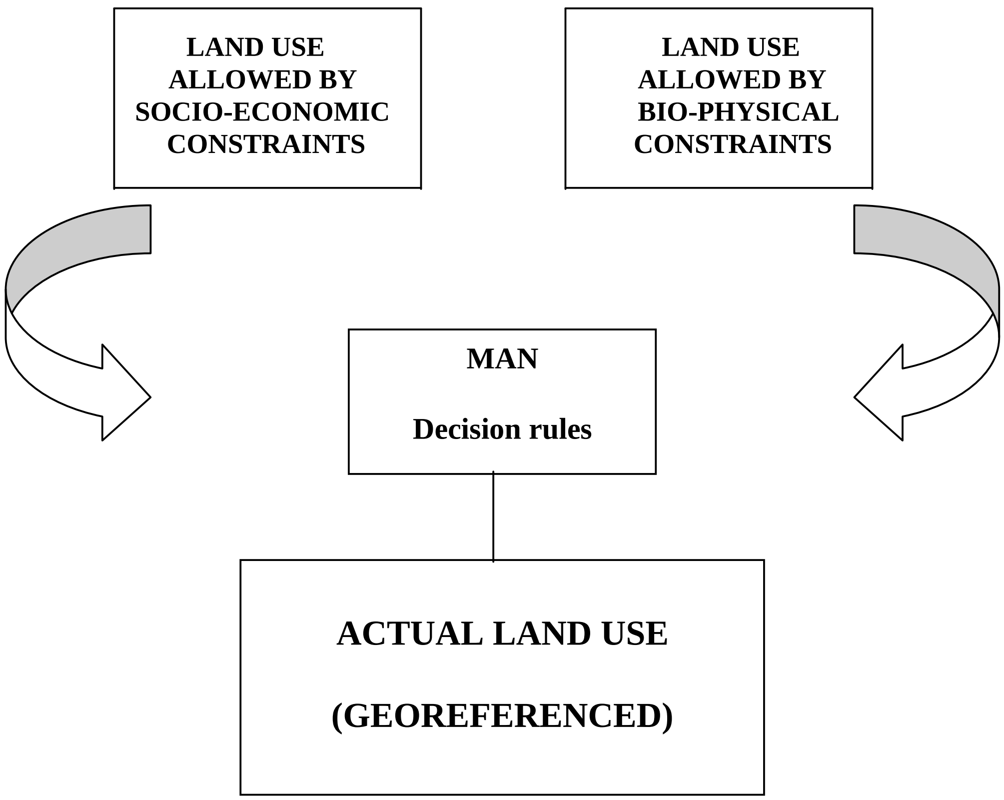
So, according to the concept of the *operation sequence* (Stomph & Fresco, 1991, Stomph *et al*.,1993) the following components have to be described to identify the land use:

The operations:

- their timing
- the traction source used for their execution
- the implements, other than traction source,, used during their execution
- the inputs applied, including the choice of species

Land use is the result of the local interaction of biophysical factors, the land resources, and socio-economic factors, which both determine the possibilities of the land user, stuck to a certain area, and can be perceived as boundary conditions of the (biophysical) land use (Figure 1).

Figure 1. Land use as a result of local interaction between socio-economic and biophysical parameters



To describe the operation sequence the time boundaries of it have to be set. In Figure 2 an example is given of an operation sequence. The farmer starts with field preparation for the seeding of maize, after which operations, such as, weeding and the application of fertilizers take place, all related to the production of maize. After two years of maize cultivation, the farmer will cultivate Spanish peppers or he/she will leave the field fallow in the third year of the sequence, all depending on the market price of Spanish peppers in that specific year. But irrespective of the fact, whether the farmer is growing peppers or not in the third year, the farmer applies the decision rule of leaving the field fallow in the fourth and fifth year. So, depending on the cultivation of peppers he will leave the field fallow for two or three years, after which he starts cultivating maize again. In this simplified scheme, the operation sequence starts with the field preparation for the cultivation of maize and ends at the moment of field preparation after some years of fallow.

Table 1. An example of an Operation Sequence

Year index	Crop	Operation
1	Maize	Ploughing, Seeding, Weeding, Fertilizing, Weeding, Harvesting
2	Maize	Ploughing, Seeding, Weeding, Fertilizing, Weeding, Harvesting
3A	Spanish Peppers	Ploughing, Seeding, Weeding, Fertilizing, Weeding, Harvesting
3B	Fallow	No operations
4	Fallow	No operations
5	Fallow	No operations
1	Maize	Ploughing, Seeding, Weeding, Fertilizing, Weeding, Harvesting

If the decision of what the farmer will cultivate totally depends on the market prices, and he/she applies no decision rules on the sequence of crops, the operation sequence can not be determined for a period longer than one year. If the land user applies biophysically based decision rules on land use, for example for a time period of 3 years after which the operations are repeated, then that period is the full length at which the sequence of operations must be described and that period determines the type of land use.

3 CONCEPT OF THE LAND USE CLASSIFICATION[2]

3.1 Guiding principles of the land use classification

Purpose: A scale independent classification, based on diagnostic properties that are a reflection of the degree of manipulation of the agro-ecosystem by the land user.

The land use classification will have as only object: *land use* as defined by *the sequence of operations, their timing, applied inputs in physical terms and used implements and traction sources.*
The history of man's use of the land for agriculture has been a history of environmental modification. Practices such as tillage, drainage, irrigation, fertiliser and pesticide application, are responses to specific environmental conditions or problems. They are an attempt to modify the environment in order to make it more favourable for agriculture (Briggs & Courtney, 1991). Land use has evolved, along a scale, from a low level of environmental manipulation, and therefore intensity (expressed in energy supply/ha), to a high level of environmental manipulation. So the degree of manipulation of the (agro) ecosystem can be seen as the logical framework for the land use classification. The manipulations of the environment are described in the operation sequences and will be used as the diagnostic criteria.

[2] The proposed concept is based on: *Describing Agricultural Land Use.* **A** draft, December 199 1. T.J. Stomph and L.O. Fresco.

3.2 The hierarchical position of the criteria

The actions of the land user can be seen as a manipulation of the environment, or in other words, it can be seen as manipulation of the factors that influence the yield. The factors that influence crop production can be divided into three broad categories (see Table 2).

Table 2. Factors that influence crop production

Yield Determinig Factors	Yield Limiting Factors	Yield Reducing Factors
Light temperature Genotype	Water Nutrients	Weeds Pest & Diseases

(source: R. Rabbinge at al, 1989)

As already stated, the manipulations of the environment are described in the operation sequence and will be used as the diagnostic criteria. For the resulting land use classes it is significant in which way the criteria are hierarchically organized. The hierarchical organization of the criteria need a logical and scientifically sound foundation. Because the factors that influence the crop production can be divided in the above mentioned three broad categories it makes sense to structure the criteria in the same way. As we know, operations can have an impact on various factors at the same time. For example the operation ploughing influences the water balance, which is a yield limiting factor, but also influences the weed population, which is a yield reducing factor. Also the degree of impact on the environment of an operation, for example, the operation fertilizing, depends heavily on the timing, the associated biophysical boundary conditions at that time, the method of application, and the quality of the fertilizer. The degree of impact also depends on the combination with other operations, for example, when weeding is done the impact of fertilizing is more profound. So, the way aspects of operations are used to provide diagnostic criteria can only be decided in an intuitive way, according to the yield factor that they influence most.

4 STRUCTURE OF THE LAND USE CLASSIFICATION

4.1 Introduction

Five hierarchical levels are proposed so far **to** classify land use. At each level a division is made into a number of classes based on one or a number of diagnostic criteria. In Table 3 an overview is given of the proposed classification with the number of major categories (4) and their number of levels.

Table 3. The classes distinguished at level 1 and the number of levels elaborated for each

level	level elaborated (+) not elaborated (-)			
1	I	II	III	IV
2	-	+	+	-
3	-	+	-	-
4	-	+	-	-
5	-	+	-	-

The quantitative boundaries of the proposed classes are only tentative. In fact, data on actual land use from all over the world will have to be classified according to this system to check on the validity of the class boundaries. Undoubtedly some of the values for these boundaries will, for pragmatic or other reasons, turn out to be unworkable.

4.2 Nomenclature and coding

The employed nomenclature reflects a choice for descriptive (self explanative) names that are relatively easily understood. The exact meaning of each class is determined by the class descriptions and boundaries. For quick (data base) reference class codes are also given. Codes at the hierarchical levels 4 and 5 are added as a combination of suffixes to the relevant codes of hi-her hierarchical levels.

4.3 Level 1: The major categories of Land Use

Principles

At the first hierarchical level the distinction between land uses is made on the basis of the severity at which the 'normal' functioning of the biosphere is changed or replaced by the land use.

Classes

I *Unused*
II *Biomass production*
III *Support*
IV *Non-biological extraction*

Class I contains those uses where physical interaction of man with the land is not aimed at manipulation of the ecosystem in order to obtain a biophysical output, e.g. virgin lands, conservation areas and waste lands. This does not mean that the land is useless to man, because it may serve e.g. spiritual purposes or as conservation area of genetic material.

Class II contains those uses where the land itself, i.e. the soil, water and/or the vegetation, is used to produce biomass of some kind.

Class III contains those uses where the land provides support for buildings, infrastructure, industry, etc. The agro-industry, e.g. hatchery (secondary production) and the production of flowers or vegetables on substrates in green houses (primary production), where the production of the biomass is not dependant on the soil or on the vegetation produced on that soil also falls into this class.

Class IV contains those uses where man extracts e.g. minerals or fossil energy from the land through excavation, mining, etc. These uses form the most severe modifications of the environment by man.

Class boundaries

Land use is considered belonging to **class IV** if the soil surface (0-10m depth) chances its aspect due to the mining/excavation. Land use is considered belonging to **class III** if the soil surface is covered by man made constructions or materials and the covered soil itself does not provide water or nutrients for the production of biomass. Land use falls under class I if extraction of biomass by man does not happen at a regular basis and not more than 1% of the standing biomass is used at any point in time.

Class II is the mandate of the LUIS working group. Although some uses falling into **class III** are also agricultural uses no attempt has been made at its classification beyond the second hierarchical level. At the second hierarchical level of **class II** the primary and secondary production will be classified separately. In this report we have limited ourselves to the primary production for reasons mentioned in the preface. In Table 4 an overview is given of the distinguishing principles at the different levels of **class II**.

Table 4. Distinguishing principles at different levels for class II 'Biomass Production'

Level	Distinguishing principles
1	The severity at which the "normal" functioning of the biosphere is changed or replaced by the land use.
2	The type of biomass production.
3	The manipulation of the yield determining factor "species" and the replacement of naturally existing cover through introduction of artificial cover or plant cover of different duration.
4	The manipulation of the yield limiting factors and tillage.
5	The manipulation of the yield reducing factors.

4.4 Level 2 for class III 'Support'

Principles

Distinctions within this major category are made on the basis of the type of production related to the artificial cover of the soil surface. Only agricultural uses will be classified here.

Classes

III.1 Production of <u>plant</u> biomass
III.2 Production of <u>animal</u> biomass

Both class names are selfexplanative. Again it is to be noted that land uses which outputs are biomass are only classified under category III if the production is not related to the soil and/or vegetation on it, in other words when the soil only provides support for man made constructions (eg. the production of flowers on substrates in green houses).

<u>Class boundaries</u>

Class III.1 contains all land use related to the production of plant biomass from light, water and nutrients (e.g. the production of orchids on substrates in greenhouses). It does not englobe land use where plant biomass is processed into secondary plant biomass products (e.g. parboiled rice).

Class III.2 contains all land use related to the production of animal biomass from plant or animal biomass using live animals (e.g. chicken hatchery). It does not englobe land use where animal biomass is processed into secondary animal biomass products (e.g. corned beef).

4.5 Level 2 for class II 'Biomass Production'

<u>Principles</u>

Distinctions within this category are made on basis of the type of biomass production.

II.1 Plant Biomass Production
II.2 Animal Biomass Production

<u>Class Boundaries</u>

Class II.1 contains all land uses where an output of the operation sequence is plant biomass.

Class II.2 contains all land uses where an output of the operation sequence is animal biomass or animal products and where an input is plant biomass browsed *in situ or* where plant biomass is added from elsewhere but the soil used for stocking of the animals is not covered artificially.

4.6 Level 3 for class II.1: Categories for 'Plant Biomass Production'

<u>Principles</u>

At this level in the hierarchy two closely linked diagnostic criteria are used, the manipulation of the yield determining factor species and the replacement of naturally existing cover through introduction of artificial cover or plant cover of different duration.

<u>Classes</u>

II.1.1 Biomass-extraction

Primary production through introduced natural cover (II.1.2):

II.1.2P Perennial cover
II.1.2A Annual cover
II.1.2AF Annual-Fallow cover
II.1.2AP Annual-Perennial cover
II.1.3 Primary production under artificial cover

Class boundaries

Annuals includes here those crops (or grasses) with an under-one-year growing cycle, which must be newly sown or planted for further production after the harvest, and those crops remaining on the field more than one year, but less than two years, and where harvesting destroys the plant (from the glossary of the land use database design of C.A. de Bie and J.A. van Leeuwen).

Class II.1.1 contains all land uses where no land cover (plant species) is added to the ecosystem while the operation sequence aims at harvesting of plant products. The only change to the land cover is through 'harvesting' of existing plant species or parts thereof.

Classes II.1.2( ) contain all land uses aimed at the production of plant biomass through the introduction of favoured species, and where no artificial cover protects the plant biomass. A further specification is made.

Class II.1.2P contains land uses where the introduced plant cover consists of any combination of perennial species only (including perennial grasses).

Class II.1.2A contains land uses where the introduced plant cover consists of any combination of only annual species. The operation sequence may cover from less than twelve months up to any number of years, as long as introduced annual species determine the plant cover in all growing seasons (no unsown fallow).

Class II.1.2AF contains land uses where the introduced plant cover consists of any combination of annual species in one or more growing seasons and where during at least one growing season the plant cover is not determined by the land user through introduction of species i.e. unsown fallow.

Class II.1.2AP contains the following land uses:

- one or more annuals followed by one or more perennials or a mixture of annual(s) and perennial(s).
- mixed planting of annual(s) and perennial(s) followed by perennial(s) or by a mix of annual(s) and perennial(s).

Class II.1.3 contains all land uses where the introduced land cover consists of artificial structures while the introduced plant cover grows in the original soil. Excluded are those cases where soil (original or introduced) is held in containers. Such systems are separated from the original soil system and thus fall under major land use category III.

In **class II.1.3** a subdivision between annual and perennial plant cover is irrelevant as the artificial cover overrules the difference in influence of plant cover duration on the agro-ecosystem.

4.7 Level 4 for classes II.1.1, II.1.2( ) and II.1.3: Categories (combined suffixes) of yield limiting factor control and tillage for all plant biomass production categories

Principles

Three diagnostic criteria are used at this level: the energy source for tillage, structures for water regulation and manipulation of nutrient balances. The three criteria are independent and so any of the 32 combinations is theoretically possible.

Classes (three combined suffixes)

- A water control through drainage or irrigation subdivided into:
  - **ac** control present
  - **a-**[3] control absent
- A nutrient addition, further subdivided according to type:
  - **na** anorganic nutrients applied
  - **no** organic nutrients applied
  - **noa** both anorganic and organic nutrients applied
  - **n-** no nutrients applied
- tillage is subdivided into:
  - **tm** machine powered tillage
  - **th** human powered tillage
  - **ta** animal powered tillage
  - **t-** no tillage

Class boundaries

The distinction between absence or presence of water control is an absolute one, even the smallest control over the water supply to the vegetation through irrigation or drainage control is considered as presence of control.

The distinction between absence or presence of nutrient application is again an absolute one. If at any point in time during an operation sequence nutrients are applied classes **na, no** or **noa** are valid. The distinction between **na** or **no** and **noa** is also absolute, if at any point in time during the operation sequence organic and anorganic nutrients are applied the mixed class **noa** is valid.

Tillage is considered present in an operation sequence if at any point in time the soil structure is directly disturbed through an operation on part or all of the parcel. Tillage is considered machine powered if the main tillage and/or maintenance tillage are executed using machine power. Land clearing is excluded as a diagnostic operation for this criterium. Tillage is considered animal powered if tillage is not machine powered and the main tillage and/or maintenance tillage are executed using animal traction. Tillage is human powered if it is present and neither animal nor machine powered.

4.8 Level 5 for classes II.1.1, II.1.2( ) and II.1.3: Categories (combined suffixes) of yield reducing factor control for all plant biomass production categories

Principles

Two independent diagnostic criteria are used at the fifth level, the type of control over weed competition and the type of control of pest and disease populations. Any of the 20 combinations is theoretically possible at each of the classes distinguished at level 4.

[3] - indicates the absence of a suffix for the indicated class.

Classes (two combined suffixes)

- Weed control is subdivided into:
  - **wc** chemical weed control
  - **wm** mechanical weed control

ww combination of mechanical and chemical weed control
w- absence of weed control

▲ Pest and disease control is subdivided into:

pdc chemical control based on a fixed scheme (calendar spraying)
pda chemical control based on population monitoring at a regional or country level (announced threshold levels)
pdm chemical control based on population monitoring in the concerned plot, or otherwise directly related **to** the present population
pdb manual, mechanical or biological control
pd- absence of pest and disease control

<u>Class boundaries</u>

Weed control is considered present if any operation of a sequence, aims at the destruction of none introduced plant species. Weed control is considered chemical if at least once during an operation sequence weeds are controlled through the use of chemical compounds. Weed control is considered mechanical if at least once during an operation sequence weeds are controlled through an operation aimed at the mechanical disturbance of the weed growth. Mechanical and chemical control may occur sole in an operation sequence or both, resulting in classification into the sole classes or the combined class respectively.

Pest and disease control is considered present if any operation of a sequence aims at the destruction of pests and/or diseases or the prevention of population build-up on the plot. Pest and disease control is considered chemical if any operation of the sequence includes the use of biocides for the control of one or more pest and/or disease population(s). Only when no biocides are used while pest and disease control measures are part of the operation sequence class **pdb** is relevant. This class includes bird scaring, application of parasite eg-s, etc. as long as not combined with the use of biocides. When one or more biocides are applied on a calendar basis against one or more pests and/or diseases the land use is classified as **pdc.** When the land use is not classified as **pdc** and one or more biocides are applied against one or more pests and/or diseases on the basis of regional or country wide monitoring of population size (e.g. broadcast information) the land use is classified as **pda.** When the land use is not classified as **pdc** or **pda** and biocides are applied against one or more pests and/or diseases on the basis of observed (estimated) population size on the plot or when baites are used which can be removed when not eaten the land use is classified as **pdm.**

5 LINK WITH THE LAND USE DATABASE AND THE AGRICULTURAL CENSUS

The land use database design developed by members of the LUIS Working Group can contain all detailed biophysical data concerning land use at field level, by its data entry module. It is important that all criteria that are used in the land use classification can be identified as code files in the land use database. Only then it is possible to classify the data in the land use database, for a certain 'unit of biophysical management', according to the land use classification. The data entry component of the land use database has been developed so far for crop husbandry and is tested in the field at different FAO projects in East Africa.

Within the LUIS working group the land use database and the land use classification have been developed parallel to each other, both based on the concept of the operation sequence. Partly the land use database and the land use classification have the same structure as will be discussed below.

The land use database has the following attribute-layers:

1) Land cover structure class
2) The operation sequence class (biophysical key attributes)
3) Socio-economic key attributes (boundary conditions)
4) Commodities
5) Produce

An example of land use data for a georeferenced unit of biophysical management in the land use database:

1) LC struct. class:	Arable annual field cropping, permanent cultivation, multiple intercropping, in a 3 year rotation system;
2) Oper. Seq. class:	Tillage class "TM", Nutrient addition class: "NOA", etc;
3) Socio-econ. class:	....
4) Commodities:	Soybean, maize
5) Produce:	Fodder

The fourth and fifth hierarchical level of the land use classification use diagnostic criteria which refer to type of data stored in the land use database in the attribute-layer operation sequence class'. The 'land cover structure' class need to be equivalent to the first, second and third hierarchical level of the land use classification. The attributes commodity and produce can always be added to the classes of the land use classification, but are not inherent criteria of the land use classification (compare with phases used in the U.S. Taxonomy soil classification).

The actual proposal for a global land use classification needs to be 'finetuned', because many quantitative class boundaries are still tentative. So it is necessary to calibrate the proposed land use classes with the actual land use information. At this point there is an obvious link with the land use database and Agricultural Census 2000. They provide data on actual land use which can be used to 'finetune' the land use classification. But at the same time it is necessary that the Agricultural Census 2000 collects data that are used in the classification as criteria, making it possible to classify the data of the Census according to the proposed global land use classification.

6 CONCLUSIONS

The drawbacks of the reviewed land use classifications have been discussed in Chapter 1. It is obvious that in the past many land use classifications have been made, but none of these fulfil the features for a sound and universally applicable land use classification. There is also a great diversity in opinion about what land use constitutes.

In this report land use for a georeferenced 'unit of biophysical management' is classified in biophysical terms, based on the concept of the 'operation sequence' (Stomph & Fresco 1991). The report concentrates on the classification of biomass producing systems. The main guiding principle for the proposed land use classification is the degree of manipulation of the environment by the land user. The factors that influence the crop production are in order of importance: yield determining, yield limiting and yield reducing factors . The diagnostic criteria used in the proposed land use classification are structured hierarchically in the same way. The resulting classification contains five hierarchical levels. The proposed land use classification **is** still far from complete and even the given class boundaries are still intuitive and need to be calibrated in the future. In the report there is a clear focus on plant biomass producing systems, which can be justified by the fact that biological use of the land always implicates plant biomass production, whether there is animal production or not. So far the report provides only a framework for a comprehensive and universally applicable land use classification and an easily understandable nomenclature. In the near future the LUIS working Group will receive a considerable amount of information on georeferenced land use, in biophysical terms, by the application of the land use data base in the field, e. g. in East Africa, making it possible to finetune the existing land use classes and to further elaborate the land use classification especially for the animal biomass producing land uses.

GLOSSARY

Annuals:
Those crops (or grasses) with an under-one-year growing cycle, which must be newly sown or planted for further production after the harvest, and those crops remaining on the field more than one year, but less than two years, and where harvesting destroys the plant (from the glossary of the land use database of C.A. de Bie and J.A. van Leewen).

Commodity:
Any population of plants or animals, or parts thereof, grown, reared and/or harvested by man (Stomph & Fresco, 1991).

Land:
"The physical environment, including climate, relief, soils, hydrology and vegetation, to the extent that these influence potential for land use".

Land cover:
"The vegetational and artificial constructions covering the land surface" (Burley, 1961).
It thus includes cultural (buildings, artifacts, fields), vegetational (grass, shrubs, trees) and other (water, burned objects and areas, soil , lithology) features on the Earth's surface.

Land use:
The direct interaction/manipulation with/of the (agro-) ecosystem by man.

Land use planning:
LUP is a form of (regional) agricultural planning. It is directed at the 'best' use of land, in view of accepted objectives, and of environmental and societal opportunities and constraints. It is meant to indicate what is possible in the future with regard to land use (potentials) and what should be done to go from the present situation to the future one, in other words, how to change land use,
(Fresco et al, 1989).

Land use type:
"The more detailed classes of land use of which specific data on management, economics, and technical inputs are given". Consists of a set of technical specifications in a given physical, economic and social setting. Attributes of land utilization types include data or assumptions on: produce and benefits, market orientation, the inputs per unit area, labour per unit area, power, know-how, infrastructural requirements, size and configuration of the holdings, land tenure, income levels (Euroconsult 1989).

Land unit:
An area of land demarcated on a map and possessing specified land characteristics and/or qualities (identical to land mapping unit, FAO, 1976)

Land use system:
A specified land utilization type (q.v.) practised on a given land unit (q.v.)

Major kind of land use:
A major subdivision of rural land use, such as rainfed agriculture, irrigated agriculture, grassland, forestry and recreation (FAO, 1976).

Operation:
One task in an activity. Always associated with a human, animal or machine power input, (FAO, 1986).
Operation sequence:

The actual sequence of operations, including their timing, applied inputs of labour and capital in physical terms and used implements and traction sources, carried out to produce one or a number of specified commodities as executed by any individual land user.

Parcel:
A single piece of land having the same tenure and physical characteristics, including irrigation facilities, (FAO, 1986).

Plot:
That part of a parcel dedicated to a particular sequence of operations.

Primary production:
The conversion of solar radiation in plant biomass e.g. annual cropping, forestry. An exception is the growing of mushrooms.

Rotation:
Fixed sequence of crops and/or fallow grown on the same area of land over a number of consecutive years, minimally 2, including situations where more than one crop is grown annually e.g. intercrops, relay crops and sequential crops, (Stomph & Fresco, 1991).

R-ratio:
Frequency of cropping in a fallow cycle (Ruthenberg, 1980).

Secondary production:
The conversion of biomass in other biomass e.g. animal husbandry, fishery.

Unit of biophysical management:
A fixed area which is manipulated by the user through a particular sequence of operations over several years.

REFERENCES

Anderson, J.R., E.E. Hardy, J.T. Roach, and R.E. Witmer (1976). *A land use and land cover classification system for use with remote sensing data.* Geological Survey Professional Paper 964. United States government printing office, Washington.

Baker, H.L. (1960). *Molokai: present and potential land use.* L.S.B. Bulletin No. 1. University of Hawaii, Hawaii.

Briggs, D. and F. Courtney (1991). *Agriculture and Environment.* The physical geography of temperate agricultural systems. London.

Burley, Terence M. *Land use or land utilization ?.* Prof. Geographer, vol. 13.

Euroconsult (1989). *Agricultural Compendium.* For rural development in the tropics and subtropics. Elsevier, Amsterdam-Oxford-New York-Tokyo.

FAO (1976). *A framework for land evaluation.* FAO Soils Bulletin, No. 32. Rome, Italy.

FAO (1986). *The FAO farm analysis package.* User's manual, volume III; summary list of important terms and abbreviations. FAO, Rome.

Fresco, L.O., H. Huizing, H. van Keulen, H. Luning and R. Schipper (1989). *Land evaluation and farming systems analysis for land use planning.* FAO Guidelines: second draft. FAO, ITC, WAU, Rome/Enschede/Wageningen.

Kostrowicki, **J.** (1983). *Land use Survey, Agricultural Typology and Land Use Systems*. Introductory remarks. Rural Systems Vol.I, No.1, pp. 1-23.

Mücher, C.A. (1992). *A discussion on land use classifications.* An amalgam of methods. A literature research, Tropical Crop Science, Wageningen. (Address: Department of Agronomy, Tropical Crop Science Section, Haarweg 333, P.O. Box 341, 6700 AH Wageningen, The Netherlands)

Rabbinge, R., S.A. Ward, H.H van Laar, editors (1989). *Simulation and systems management in crop protection.* Simulation Monographs 12. Pudoc Wageningen.

Ruthenberg, H. (1980). *Farming systems in the tropics.* Third edition. Clarendon, Oxford.

Scace, R.C. (1 98 *1). Land Use Classification Systems.* An overview. Working paper No. 14. Lands Directorate, Canada.

Stomph, T.J. and L.O. Fresco (1991). *Describing agricultural land use. (*A proposal for procedures, a database and a users' manual to be incorporated in a FAO Soils Bulletin). FAO, ITC, WAU, Rome/Enschede/Wageningen.

Stomph, T.J., L.O. Fresco and H. van Keulen (1993). *Land use system evaluation; concepts and methology.* In Agricultural Systems (in press).

Swinton, S.M. (1983). *Peasant farming practices and off-farm employment in puebla, Mexico.* Cornell International Agriculture Mimeograph 99. Cornell University, Ithaca, New York.

OTHER CONSULTED SOURCES

Beek, K.J. and J. Bennema (1972). *Land Evaluation for Agricultural Land Use Planning.* An ecological methodology. Department of Soil Science and Geology, Wageningen.

Blokhuis, W.A. (1988). *Soil Classification.* Department of Soil Science and Geology, Wageningen.

Bowles, E.J. and D.P. Garrity (1988). *Development of a comprehensive classification for Rice Ecosystems.* Paper presented at IRRI special seminar. International Rice Research Institute, Los Banos, The Philippines.

Bunting, A.H. (1986). *Agricultural Environments: Characterization, Classification and Mapping.* Rome.

Dalton, G.E. (1975). *Study of Agricultural Systems.* Department of Agriculture and Horticulture, University of Reading, England.

Chudleigh, P. (1976). *The Use of Classification and Description of Animal Production Systems in the Formation of Priorities for Agricultural Research in Kenya.* In Agricultural Systems No.1, pp. 281-299. Applied Science Publishers Ltd, England.

Dent, F.J., J.R. Desaunettes and J.P. Malingreau (1977). *Detailed Reconnaissance Land Resources Survey Cimanuk Watershed Area (West Java).* A case study of land resource survey and land evaluation procedures designed for Indonesian conditions. Working Paper No.14, Soil Research Institute, Bogor, Indonesia.

Duckham, A.N. and G.B. Masefield (1970). *Farming Systems in the World,* London.

Evenson, J.P., D.L. Plucknett and I.Horton (1970). *A Proposed Classification for Agricultural Systems*. In Proceedings of the Second International Symposium on Tropical Root and Tuber Crops. Vol. II, pp. 63-69, Honolulu, Hawaii.

FAO (1976). *Programme for the 1980 World Census o Agriculture.* FAO Statistics Series No.1.

FAO (1984). *Guidelines: Land Evaluation for Rainfed Agriculture.* FAO Soils Bulletin 52.

FAO (1985). *Farm Management Glossary.* FAO Bulletin 63.

FAO (1986). *Guidelines: Land Evaluation for Extensive Grazing.* FAO Soils Bulletin 58.

Fresco, L.O. and E. Westphal (1988). *A Hierarchical Classification of Farm Systems.* In Experimental Agriculture., volume 24, pp. 399-419, Farming System Series-17.

Gils,van H. (1989). *Legends of Landscape Ecology Maps.* ITC Journal 1989-1, pp. 41-48. Enschede, The Netherlands.

Gils, van H., H. Huizing, A. Kannegieter and D. van der Zee (1991). *The Evolution of the ITC system of rural land use and land cover classification* (LUCC). ITC Journal 1991-3. Enschede, The Netherlands.

Getahun, A. (1978). *Agricultural Systems in Ethiopia.* In Agricultural Systems No.3. Applied Science Publishers Ltd, England.

Grigg, D.B. (1974). *Agricultural Systems of the World.* An evolutionary approach. Cambridge University Press.

Heady H.F. (1981). *Multiple Uses of Rangelands*. Grazing Animals, World Animal Science, B1, pp. 225-237. Elsevier Scientific Publishing Company, Amsterdam-Oxford-New York.

Holdridge, L.R. (1967). *Life Zone Ecology*. Tropical Science Centre, San Jose - Costa Rica.

Huijsman, A. (1986). *Choice and uncertainty in a semi-subsistence economy.* A study of decision making in a Philippine village.

IGU (1949 ?). Report of the Commission to study the possibility of a "World Land Use Survey".

IGU (1976). World Land Use Survey. L'utilization du sol dans le monde. Report of the Commission to the General Assembly of the IGU. Geographica Helvetica Nr.1 - 1976. Kümmerly & Frey, Bern Switzerland.

ILRI (1984). *Proceedings of the Workshop on Land Evaluation for Extensive Grazing (LEEG).* ILRI publication 36 (Editor: W. Siderius).

IRRI (1984). *Terminology for Rice Growing Environments.* International Rice Research Institute, Los Baiios, Laguna, Philippines.

Kannegieter, A. (1988). *Mapping Land Use*. In Vegetation Mapping, Handbook of Vegetation Science, pp. 335-374, edited by Küchler, A.W. and I.S. Zonneveld. Dordrecht: Kluwer Academic Publishers.

Kostrowicki, J. (1977). *Agricultural Typology Concept and Method*. In Agricultural Systems No.2, pp. 33-43. Applied Science Publishers Ltd, England.

Kostrowicki, J. (1984). *Types of Agriculture in Europe*. A preliminary outline. Geographia Polonica 50, pp. 131-149.

Mather, A.S (1986). *Land Use.* Longman Group U.K. Limited.

Morgan, W.B. and R.J.C. Munton (1971). *Agricultural Geography.* Methuen & Co Ltd, London.

Remmelzwaal, A. (1989). *Classification of Land and Land use.* FAO, internal report. Limited distribution.

Rhind, D. and R. Hiidson (1980). *Land Use.* Methuan, London & New York.

Rjabehakov, A.M. (? *) World Map on Actual Land Use at 1:15,000,000.* Faculty of Geography, Moscow State University.

Schwaar, D.C. (1973*). Land Use Dynamics and Transmigration in Southern Sumatra*. In Proceedings of the Second Asian Soil Conference Vol. I, pp. 189-238. The Soil Research Institute Bogor, Indonesia.

Spedding, C.R.W. (1988). *An introduction to Agricultural Systems.* Second Edition. Essex, Great Britain.

Stamp, L.D. (1961). *A History of Land Use in Arid Regions.* Arid Zone Research, UNESCO.

UNESCO/UNEP/FAO (1979). *Tropical Grazing Land Ecosystems.* Natural Resources Research XVI.

Vink, A.P.A. (1975). *Land Use in Advancing Agriculture*. Advanced Series in Agricultural Sciences I, Springer-Verlag, Berlin, Heidelberg, New York.

Westphal, E. (1975). *Agricultural Systems in Ethiopia.* Pudoc, Wageningen.

Whitby, M. and J. Ollerenshaw (1988). *Land-Use and the European Environment.* Belhaven Press, London & New York.

Williams, O.B. (1 98 1). Evolution of Grazing Systems. Grazing Animals, World Animal Science, B1, pp. 1-11. Elsevier Scientific Publishing Company, Amsterdam-Oxford-New York.

Zonneveld, I.S. (1979). *Land Evaluation and Landscape Science.* ITC-textbook on photo interpretation. ITC, Enschede, The Netherlands.

Zonneveld, I.S. (1988a). *Basic Principles of Land Evaluation using Vegetation and other Land Attributes.* In Vegetation Mapping, Handbook of Vegetation Science, pp. 335-374, edited by Küchler, A.W. and I.S. Zonneveld. Dordrecht: Kluwer Academic Publishers.

Zonneveld, I.S. (1988b). *The ITC Method of Mapping Natural and Seminatural Vegetation.* In Vegetation Mapping, Handbook of Vegetation Science, pp. 401413, edited by Küchler, A.W. and I.S. Zonneveld. Dordrecht: Kluwer Academic Publishers.

CASE A Pineapple lands in Hawaii

Land preparation:

The old plants are knocked down and chopped with a disc or cut-away harrow. The field is ploughed at least three times, subsoiled once or twice, and harrowed after each ploughing. It may take from 4 to 6 months to complete field preparation.

Preplant operation:

After the initial field preparation is completed, mulch paper is laid on the clean tilled or trash mulched fields. About 400 pounds of DD (soil fumigant) is placed on the mulch paper.

Planting:

Between 14,000 to 18,000 slips, suckers, or crowns are planted per acre, by hand.

Weed control:

Pre-emergence herbicide is applied immediately after planting. Initial application is at the rate of 4 pounds of CMU or its equivalent to the acre. It is followed by 2 pounds of CMU to the acre. Additional weed control measures include use of contact oil herbicides, with sometimes up to hours of hand weeding per acre.

Irrigation:

Where the land classification noted or assumed irrigation, a minimum of water is expected to be applied whereby insurance against crop failure rather than maximum yields were the objective.

Fertilization:

Nearly all the pineapple lands are cropped continuously so heavy applications of chemical fertilizers are the usual practice.

Insecticide:

To control ants and mealy bugs, 24 pounds of Malathion or its equivalent are applied to the acre during the crop cycle.

Age:

Average plant crop age is between 22 and 24 months. The ratoon crop follows in 12 to 14 months. For an average cycle, it takes 4 years, including the time required for land preparation.

Classification:

II.1.2P.ac.na.tm.ww.pdc

Source: Baker, H.L. (1960). Molokai: present and potential land use. L.S.B. Bulletin No. 1. University of Hawaii.

CASE B Corn cultivation in a community near Heujotzingo, Mexico

<u>Land preparation:</u>

Mules are used for land preparation. Virtually all draft animal owners have a mouldboard plough.

<u>Handtools:</u>

Wheelbarrow, shovel, pick, hatchet, sickle and machete.

<u>Cropping pattern:</u>

Monocropped maize. All the maize planted is open-pollinated flour corn (Zea mays amylacea). Most seed had been saved from the previous harvest. The maize is planted by two or three seeds per hill with hills 50 cm. apart in rows separated by 90 cm. Amounting 55,600 plants/ha.

<u>Weed control:</u>

Sprayers are used for herbicide application on maize, next to mechanical weeding.

<u>Irrigation:</u>

No irrigation.

<u>Fertilization:</u>

All farmers fertilise their maize. Both manure and commercial fertilizers are used. The commercial fertilizer used is urea. (40-0-0) and a blended fertilizer with a 18-46-0 analysis.

<u>Insecticide:</u>

Not used

<u>Classification:</u>

II.1.2A.a-.noa.ta.ww.pd-

Source: Swinton, S.M. (1983). Peasant farming practices and off-farm employment in puebla, Mexico. Cornell International Agriculture Mimeograph 99. Cornell University, Ithaca, New York.

CASE C Shifting Cultivation: manioc-cotton holdings (hoe cultivation) in the Central African Republic.

Cotton, the cash crop, is planted first after clearance, and is followed in the second year by an association of sorghum, groundnuts, and several legumes and grain legumes. Most of the second-year plot is interplanted with manioc, which is the third year`s crop, and at the same time some kind of tumbledown fallow. On average 3 crop years are followed by 6.5 years of bush fallow.

Land clearance is done by men, often in groups. Tools are the only purchased inputs (implements). Prices in the area were such that the use of fertilizer did not pay.

Assumptions: there is no water control and no nutrients are applied. Some weeding is done by hand, but there is no P&D control.

Classification:

II.1.2AF.a-.n-.th.wm.pd-

Source: Ruthenberg, H. (1980). Farming systems in the tropics. Third edition. Clarendon, Oxford