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Clarion University of Pennsylvania, Clarion, Pennsylvania

# GIS/REMOTE SENSING METHODOLOGICAL FRAMEWORK OF LAND RESOURCE USE FROM THE FULANI PEOPLE GEO-CULTURAL PERSPECTIVE, NORTHERN SENEGAL

By: Ahmadou Sadio Dia

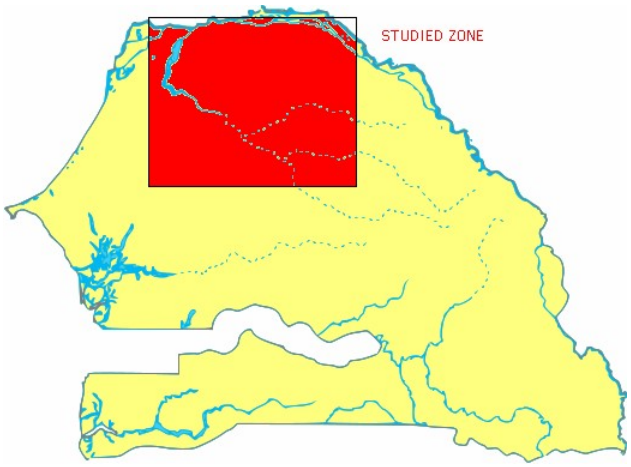
## ABSTRACT

A comparative traditional-knowledge based contribution from a given socio-cultural group to the epistemological base of the land resource. The principles, methods and techniques of land resource survey, evaluation and planning for coomunity development are explored. The examples, as outcomes from the plant -since it constitutes a synthetic land resource- are designed as a geographical information system to be an information support service for scientists, planners and decision-makers.

Keywords: Resource, Land Degradation, Conservation, Semi arid, Sahel, Land Use, Community Development, Environment, GIS/Remote Sensing, Traditional Knowledge-Sharing

## INTRODUCTION

The geographical area of study (15°00'00"N // 16°30'00N and 13°00'00"W // 15°20'00"West) is situated in the north-western part of the Senegal River Basin. It covers the traditional regions of *Fuuta-Tooro* (Senegal River Valley) and the *Ferlo* low plateau. The settlers in this zone are mainly farmers, agro-foresters and pastoral groups, all of them derived from the old Ful Culture (called *Fulani* in English, *Peulh* in French, and calling themselves *Fulbe i.e.* the *people of Ful*). The zone is a complex of two ecosystems divided into 11 geosystem types that are subdivided into 28 geofacies /geotope categories.




For half a century, some scientific investigations have been carried out in this bioclimatic zone - between 200mm and 400mm isohyetes. However, many research fellows, planners and decision-makers are still often frustrated by the content of land resource documentation in terms of its inconsistency, its incoherence and the unintelligibility of the edited land resource maps. For a significant period of time, the author of this article has also been confronted with the same thematic challenging difficulties, as follows: (i) conceptual clarification from a common understanding of what the concept land resource actually means, (ii) the relevance of a conceptual framework in terms of principles, methods and techniques of land resource mapping, survey and evaluation for local and regional development planning, (iii) the opportunity for expertise and knowledge to be shared between the local and transregional levels by using the earth observation and geoinformation science outputs as inputs. Finally, some found results will be attached as an example of a database for futher international cooperation through geographical comparison. The interest of this results database is a logic of conciliation between the modern technology approach and the local traditional knowledge one.

## CONCEPTUAL AND OPERATIONAL FRAMEWORK OF LAND RESOURCE MAPPING AND SURVEY

The usual routine process to overlay different thematic maps to obtain synoptic and / or synthetic diagrams is a necessary but an insufficient step to comprehend the land resources concept. In actual fact, one is only able to have a comprehensive perception of the natural conditions (in terms of their processes and associated forms according their structure and evolution) and from how they are represented on a topographical base map. These patterns are often called land resources. Subsequently difficulties arise as each land specialist understands his / her own area of concern as land resource. The planner and the decision-maker attempt to see the relationships in order to

*interpret* the natural conditions, properties or attributes into land resources. What should be then the meaning of the land resource concept?

**Theoretical corpus of Land Resource**

For example, W.FIREY, in *Man, mind and land:a theory of resource use*, 1960, defines resource as "…a given combination of cultural and bio-physical factors…". This is understood as resource process, as a capitalized natural space component. In addition, a given set of resource processes yields as resource system. That is to say, from Firey's equation, a resource is man-mind-land structure. Following from this point, a given land resource process is a natural-cultural part of space capitalized within a space-time sequence (expressed as land-use system). In this view, what is the best way to interpret such general and artificial abstractions as limited resource, unsustainable resource, sustanaible resource or permanent lack of resources? etc. Moreover, W.FIREY, 1960, underlines two basic properties of land resource: a resource complex that shows some consistency and stability in the face of external changes (while land conservation practices constitute the land degradation mitigation) and resource congeries that do not show much stability and vary widely within a socio-ecological context (when the land degradation process is the main process of the landscape building).

From a methodical view, land resource can be mapped , surveyed and evaluated from:

(i) *the geo-ecological analysis* that essentially uses the properties of equilibrium, stability, retroaction and auto-regularization, bearing in mind the search for an ideal situation - that is to say the stage of ecological climax-. It would be correct to call it an anthropogenetic climax since it is always interpreted through human occupancy. This requires a land resource mapping and survey to be coupled with a land degradation mapping and survey, at the same time. Land resource and land degradation are the two facets of the same reality. The standard so-called land resource mapping does not disclose and display the climax phases that are necessary for the land use planning perspective. What is often shown is a comprehensive bio-physical data inventory. Then the myth of biodiversity arises while only reduced to the ecological perspective;

*(ii) the cultural interpretation* suggests that there is no land resource as such since land resource is the result of human activities (again, this is never sufficiently explicit when reading the usual edited maps). FIREY, 1960, suggests that a resource complex may or may not be adaptable within a cultural consistency. This introduces the potentials and limits of intercultural or transcultural diffusion. Then, would a resource system be from a monogenetic or polygenetic origin? Why not

considering the wider concept technodiversity or geodiversity, if it is true that human societies develop cultures in different ways as a result of their own specific experiences? The tragedy be falling any particular culture is the result of their being somehow blind to some resource process values that other cultures have produced, conserved or developed. Culture could be said to be like the human being: both best and worse forms coexist. The technodiversity and its wider spatial-time extension and expression the geodiversity from which the resource system develops, suggests then the logic of equity for the information production and circulation has nothing to do with what is just called technology transfer. Often the objectives of comparative land resource map design do not proceed in this direction because certain ideological and political issues are overriding or interfering. Resource process stems from the faculty of creation (translation of natural conditions into land resource) that supposes a logic of freedom. What is then biodiversity without any reference to a given social and cultural context?. The limiting concept biodiversity is a product of western-oriented academia that controls the mind of the international public cooperation.This , specially when the environmentalism as ideology and ecocratie as powerfull control instrument are confused with the scientific objectivity.Where biodiversity is alerting the geopolitical demand should be present too. Although the ecological perception is scientically sound, what is regrettable is its ideological and political manipulation , i.e. meaning resource control issue. The concept geodeversity is not new, it is old as the mankind praxis since it discloses the different interpretations of the nature in their full space-time dimension. In this respect, it is not surprising that the socio-geographical analysis and synthesis ability provides the full intellectual acceptancy of the concept land resource.

*(iii) land economy paradigms* providing dogmas such as rentability/profitability, «efficiency/efficacy» and «productivity» often consider only a basic operational concept:cost-benefit analysis. In the Sahel West African zone, , land economics models are very often used and inspired . from the works of von Thunen, 1875, to those of Anckermann , 1963, C. Sauer 1952, Morill 1970, and Isard 1963, as do those derived from the Marxist-leninist political economy (A.A.Minc,1976; N.Kolossovski,1975). Although some agro-economic equations are applied for rural planning projects design, the spatial-time models are often ignored. Land resource evaluation should look at the dialectic relationships between resource complex and resource congeries.

A resource complex is an anthropogenetic climax and is evaluated by using the equation:

$$R = Ep * Ta * Sg * Ee * Ca$$

R = resource complex; Ep=Ecologically possible; Ta = Technically adaptable, Sg = Socially gainful; Ee = Economically efficient, and Ca = Cultural acceptance.

This is ideal for general use but the geographical reality (out of the techno-geodiversity) remains significantly more relevant.

The geo-cultural experience of the Fulani people, in terms of the economy of nature considers much more basic paradigms that are:

- a resource process is to be found from the basic topological components such as *Tufnde (*water source site*), a Durungal* (pastoral range management scheme unit), a *Jofnde (*corral park for cattle*),* a *HoDorde (*Human Settlement*)* and a *Gentu (*site of the ancestors spirits, marked by esoteric symbols signs and expressed only by a secrete language*).* These topological components are always linked by a *Lappol* network (paths for wild and domestic animals). From this perspective, the strategies of nomadism and sedentarization are simply the most extreme forms of solving the problem of this contradiction by maintaining the balance between these components. Neither of these is notably better than the other since they are simply flexible problem-solving strategies and not an absolute and definitive solution. The task of land resource planning would be to simply facilitate this kind of self-organization within a given territorial community by maintaining this logic of permanent relative balance.

- a resource-process is only able to be evaluated and is only valuable in terms of the cosmic and biological rules of correspondence: the *Ngenu*-Nature/Godesss (simplified as land resource) is a result of the cross-junction of the spirit (simplified in the human mind) and the interface between subtle matter and dense matter. In this view, the knowledge discourse is the result of two main sources, such as science and magie (especially in terms of the ability to understand the animal and human-related destiny as a given factor / vector or indicator of resource process called "*Beydaari-Danyal"*). These two forms of knowledge neither interfere nor alternate in the Fulani vision: they coexist within the same knowledge praxis and management. This is due to the neolithic agro-pastoral revolution in Eastern Sahara-Nile Valley, the cradle of Fulani Culture.

- the *Leydi* Land concept, both as material and spiritual substrata of a resource process, is considered as a Divinity (clearly as a set of personified natural and social laws). It would not therefore be appropriate to talk about resource management but instead about *managing with land resource* since a resource process or resource system is considered as an emanation of the *Ngenu* (i.e. the Nature/Goddess). That is to say a resource process cannot belong to the Human Being. Here only the principle of *usus* but not *abusus* applies because the *fas* contains and goes far beyond the *jus.* More appropriately, the principle of resource access for all human beings has to be guaranteed and the *fas* introduces the holiness of the concept of sustainability before its apparition in modern literature

(from the basic principle of eternal and continued conservation out of transmission of land resource). The arising difficulty is how to design a conceptual and operational framework from a neo-traditional and modern perspective (without the unnecessary "westernization" through uncontrolled globalization ). This, because the land tenure system which is considered to be modern is often based on so-called statutory law which is also the traditional law exported and imposed from the most traditional indo-european laws, expressed by the so-called roman law. This does not permit either the cultural diversity that would be necessary for geodiversity nor the fact that the traditional land laws could also be updated and modernized without to be westernized at any rate.

**Graphic of Land Resource evaluation for Development Planning**

A polythematic and factual-synthetic cartography presents only the natural conditions, while a polythematic and operational synthetic cartography displays the land resources. These types of cartography are the two different and complementary ways of mapping and surveying. Hydrology and hydrogeological maps, botanical and vegetation maps are examples of the thematic mapping of natural conditions, and the water resource / water reserve and water use maps are examples of resource mapping. The inevitable law of dynamics demands a logic of anticipation in order to comprehend the resource complex-resource congeries relationships. That means that land resource evaluation involves looking at the two dynamics simultaneously:

(i) demands for change through the resource development policy and resistance to change from the resource conservation praxis. Resource development means transforming the natural conditions within a situation of *instability* (i.e. Land Degradation or Environmental Risks);

(ii) resource conservation involves a circulating social capital within a stable ecological and social order ruled by social justice (when Land Administration acts as an instrument for free land access for all).

As a result, a land resource mapping and survey gets a sense and a function only while having an explicit land resource planning project. The term graphic provides a prospective view and reflects also the social collective memory, i.e. the geo-historical component, as a living witness of the geosophical approach from the Fulani experience. Planning by resource development / resource conservation (like two enigmas that are contesting and completing each other, neither of them overcoming the other) is read simultaneously in the two types of maps with one double legend - table : i.e. a land-use map associated with a land degradation map (as a transparent overlay). In the same way, a land use planning cartography being linked to the land conservation one. The first acts like a cover of a recipient and the second as the recipient itself. In this way they can be considered in a

resultant perspective for both descriptive and prescriptive goals - i.e. the full application of the dual concept of land resource planning (land development / land conservation). Drawing the graphic of this documentation was only half -sufficient if it were not completed by an explicative notice that does not repeat what the graphic is showing but clarifies what the graphic itself cannot convey. The notice is a compact explanation of the land use code, specifying in addition the users-actors of land resource planning subjects and the land uses categories as objects of planning.

The idea of resource conservation discloses some ethical and esthetic properties: from the Fulani geosophical approach, the term *Nyeenyal,* means good and beautiful both in a physical and in a symbolic sense. In terms of a more practical objective, the simultaneous evaluation of resource development and resource conservation yielding the resource planning discloses social development in terms of indicators, vectors and actors, like the circulating blood within an organism. In this respect, it is was suitable to design a set of tables by representing the land resource complex on the abscise X segment and land resources congeries on the ordinate Y segment or, using the same logic, by representing the land resource conservation in the X abscise segment and the land resource development in the Y ordinate segment. This set of tables designed within a time series taxonomy (for example: project cycle, programme echeance and plan horizon) can constitute the conceptual framework for a GIS as a decision-support tool for Local and Regional Development Planning. The function of a graphic can only be fully utilized if designed within a Local and Regional Planning context; this would be the best way to look forward to the anticipated development policy and strategies.

## PRACTICAL ISSUES: LAND RESOURCES MAPPING AND SURVEY PRINCIPLES, METHODS AND TECHNIQUES

This contribution will focus on the most common and significant example of the land resource process: the plant as an ultimo synthetic result and expression of a natural condition transformed into land resource.

### Guiding Principles

On top of a strict botanical survey and inventory (using both their latin binome designation and the Fulani language nomenclature), more investigations and display levels were added, such as: (i) the ecological sites topology within their land cover classes context, (ii) their usual corresponding land use types and / or land utilization categories, (iii) their phytocynetical phases interpreted as anthropoclimaxic situations, (iv) their practical uses (in terms of animal and /or human foods,

medical resources, wood for fuel to provide energy, handcraft and human settlement construction material), (iv) their cultural values and magico-social symbols, and, last but not least, (v) their land conservation that involves land husbandry properties or their land degradation characteristics indicators.

These principles are based on the spatial analysis laws of seriation, location and particularly on the scale taxonomy. By doing so, it was possible to create a whole database comprising a set of tables in which: (i) each plant, as a resource, is evaluated in terms of geo-ecological properties and situations and considered either as a resource conservation or a resource development; (ii) each plant resource process is seen either an example of resource complex or resource congeries.

**Methodology and Techniques**

Methodology is understood as a comparative study of various and complementing methods in terms of their nature, properties and functions, as shown in Table 1. Six different methods have been selected and used. Each method is linked to a suitable set of specific remote sensing sources as inputs:

(i) Method I, deals with seriation of spatial taxonomy and topological transformations linked to the concept of satellite images inputs spatial resolution in terms of the sampling precision, size and scale;

(ii) Method II, for the physical and chemical characteristics survey, focuses on the spectral range and spectral resolution (based on existing Hyperstral Data Library for Semi Arid Ecosystems such as Hapex Sahel);

(iii) Method III, takes into account the temporal dimension through to the phenological sequence analysis, monitoring and modelling and focuses on the temporal resolution interpretation;

(iv) Method IV provides the bio-physical characteristics and is based on the radiometric conversion into intensity of information (from the contrast levels) by reading the radiometric resolution;

(v) Method V, called evidence, allows the validation of the collected data transformed into information to be used as evidence for the final knowledge- building. Because it is able to present all this in digital graphical format as a set of tables, it provides a Land Information System: the sampling + image interpretation + supervised classification;

(vi) Method VI, is the synthetic process for knowledge-sharing and common decision-support for land resource planning and management. This constitutes the last step and

is based on the concept of facilitating communication more quickly and easily :table + diagram + matrix or image diagram file or map + image + text.

Table 1 shows that, at each geo-ecological taxonomy level, the most suitable and relevant method is used to evaluate a given resource process. There is no an absolute “best” or “superior method”. Each method has its own potentials and limits. Only a comprehensive approach -a view from the bridge- can be operational for an integrated land resource evaluation. Just as some different notes are necessary to make music but it is a given combination of notes that provides the required melody or rhythm. The same principle applies to the selection and combination of methods for methodological framework configuration.

**Table 1: A methodological framework of land resource mapping, survey and evaluation**

| **Method I: Seriation and topological transformation** | **Spatial Taxonomy *1** | **Geotope** | **Géofacies** | **Geosystem** | **Ecosystem** |
|---|---|---|---|---|---|
| | Scale | 1: 5 000 | 1:10 000 | 1:50 000 | 1:200 000 |
| | | | | | |
| | Spatial resolution | 1m in Panchromatic image ; Digital Terrain Model + Ortho Rectified Image | 2.5m Panchromatic image ; 3 D Relief Shadows | 10m, Panchromatic image ; 3 D Grey Levels | 30m in Panchromatic; 3 D level curves |
| | Site sample size | 20m x 20m | 500m x 100m | 20km x10Km | 200Km x 200 Km |
| **MethodII: Chemical analysis according to phenological sequences** | Spectral range | Infra Red (0.7 - 2.5mm) for Leaf Area Index (N, P, K) (HYPERSPECTRAL DATA) FUSION:LIBRAIRY ))DL'USGS) | MW (7.5 nm - 11nm) Normalized Differential Vegetation Index | VIS-R + Radar-P/L Bands Normalized Differential Vegetation Index | Infrared /VIS /Radar X/C Bands Green Vegetation Index |
| | Spectral resolution | 10 nm | 50nm | 100 nm/ 128 Bands | 200 nm |
| **Method III: Time seriation** | Observation frequency (Temporal Resolution) | 2 times /year (biannual : April dry month and September wet month ) | 4 times /year (4 seasons) | 13 times /year (13 ecological -periods of 28 days each) *4 | 28 times /year (28 ecological -periods of 13 days each |
| | Sensors Sources | Quick-Bird + HYMAP + ASTER/NASA | SPOT-HRV | SPOT-VEGETATION + LANDSAT-TM | Synthetic models:MODIS//TERRA + HVS-Resours01 *4 |
| **Method IV: Bio-physical parameters** | Radiometric resolution | 8 Bits/255 Grey levels maximal contrast | 8 Bits/255 Contrast levels (Far Iinfra Red Red –Bush Fire Tracking) | 8 Bits / 255 Contrast levels | 8 bits/255 Contrast levels |

| | | | | | |
|---|---|---|---|---|---|
| **Method V: Validation by graphic semiology** | Identification, Survey and Mapping *3 | Floristic nomenclature /identification and collecting on sites + ethnological and botanical-ground investigations | Sites sampling + Photointerpretation-1 + Non -Supervised Classification | Photo-interpretation 2 nd level: + Supervised Classification + Generalization / Validation | Digital Cartography |
| **Method VI: Synthetical transformation of the data forms and formats** | Analyze/Processing/ (Communication of the information) | Table / diagram/ matrix (Analyze) | Image file /diagram (Processing) | Image/ file- matrix (Processing) | Map / Image + Text (Communication) |

*1. Bertrand, G. (1968) and Tricart, J.F. (1979): Taxonomie spatiale; *2. Campbell, J. (1996): data forms compression and transformation law + Hyperspectrale Data Libraries (NASA/USGS –ASTER and in Australia: HyMap+ Hapex-Sahel) + Compromise law between spatial, spectral and radiometric resolutions that determines the data inputs and their processing costs; *3. Bertin. J. (1972): graphic data transformation into information classes = resource process (data consistency); *4. According to the stellar-inspired local calendar that divides a year into 28 sequences. Each sequence corresponding to a given star name and to an ecological period (called eco-period). In terms of temporal resolution this type of calendar is more suitable for the land resource monitoring and modelling. The technology follows the demand of cultural tradition and not the other way around**.**

**Abbreviations in Tab.1.**

DTM = Digital Terrain Model
3 D = 3 dimensions (X, Y, Z)
PAN = Panchromatic Image
IR= Infra Red
LAI = Life Area Index
NDVI = Normalized Differential Vegetation Index
MW = Microwave
VIS = Visible
GVI = Green Vegetation Index / Global Vegetation Index
MODIS = Moderate Resolution Imaging Spectrometer
ASTER = Advanced Space borne Thermal Emission and Reflection Radiometer
SPOT = System Probatoire d'Observation de la Terre
HRV= High Resolution Visible
TM = Thematic Mapper
FIR= Far Infra Red
RADAR L, P, and C/X Bands

## RESULTS AND DISCUSSIONS

The results of the survey are presented in Table 2 (annex) in the form of database structure. The best way to read it is to bear in mind that each line expresses a species of plant as a resource process (T = Tree / Shrub or G = Grass). The plant names are given both according to their international botanic nomenclature in column 1 and to the Fulani language in
column 2.

Then 58 tree / shrubs and 28 grass species types of resource process have been sampled and their site surveyed and mapped. The 3rd column indicates the topological parameters of the resource process from the ecological site and the land cover context. The 4th column translates the land use type properties involving the land use planning issues. The 5th column is the most significant since it expresses the dynamic of resource process out of its anthropoclimax expressed trends. It allows to interprete a given plant either in terms of resource complex or resource congeries. In this way it suggests planning in terms of a balance between the conservation and the development. This column constitutes essentially the legend of the corresponding land degradation thematic map. The 6th column translates the meaning of the plant in terms of land husbandry potential in the strategy of combating desertification at the local scale (1:20 000) and from the available material as resource systems. The last column expresses more explicitly the resource processes in terms of their practical uses (human food, fodder, human and veterinary medicine, energy sources, handcraft, construction material and cultural symbols values).

This database, together with a futher digital map, yields a Geographical Information System for resource planning. (Annex: Table.2. Resource processes database from geo-cultural persception and GIS-Remote Sensing techniques ).

## CONCLUSION

This methodological framework has attempted to show that there is no single method suitable for resource mapping, survey and evaluation. In this respect, only the methodology can integrate the most striking aspects and noteworthy facets of the concept land resource. Other rsearch fellows from areas which are similar in terms of natural conditions but different in terms of cultures could also extend and exchange this type of database via internet. They could do this by providing the same data file types for responses/solutions to given questions/responses for many land use stakeholders.

This would be the purpose and the function of the concept geodiversity , i.e. going beyond the restrictive biodiversity concept to look at the real ideological and political challenges which exist between the human groups and the scientific or political lobbies. The logic of fair information exchange between different and complementary cultural groups is not a new concept, but the threat of information monopoly is now becoming clear. Even we, the research fellows from the so-called "Third World" (historically, Africa, the Great Oceania, Latin America, and Indian subcontinent constitute the ancient First World, geographically this complex is also the present and future First World in terms of land resource geodiversity potentials) may have limited technology, the international telecommunication network could help. This small contribution attempts to pursue these issues in this direction.

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## ANNEXE. Table 2. Results : Resource Processes Database from geo-cultural approach and GIS/ Remote Sensing survey and mapping

| **Botanical name (international nomenclature)** | **Plant-resource name in Fulani language** | **Ecological site / Land Cover context** | **Land Use type** | **Phytocynetical phase** | **Resource Conservation or Resource Development function** | **Practical resources uses** |
|---|---|---|---|---|---|---|
| *T1.*1* *Securidaca longepedunculata* | Aalali | Sandy low plateau steppe | Range management scheme | **?** | Reforestation | **?** |
| *H1*2* *Cassia occidentalis* | Aljannahi | Herbaceous old fallows and ancient human settlement site. | Settlement | Postclimax | Land Degradation indicator | Human Medicine (cures fever and headache) |
| *H2.* *Cassia Tora* | Uulo | Vertisols along low plateau talwegs | Settlement | Anthropoclimax | Land Degradation recovery indicator | Human Food Crop |
| *T2.* *Acacia Siberiana* | Alluki | Loamy low plateau woodland savannah | Forestry / Range Management Scheme | Penestable Hydroclimax | Land Husbandry for Forest t-Restoration | - |
| *T3.* *Calotropis proceroa* | Bawaami | Old fallows / very degraded steppe (sometimes archaeological site indicator) | Settlement | Post climax | Land Degradation indicator | - |
| *T4.* *Entada africana* | Baccari | Sandy plateau woodland savannah | Range Management | Peneclimax | - | - |
| *T5.* *Commiphora africana* | Baddi | Loamy-sandy Inter-dune depression degraded steppe (on the outcropping Continental | Range management Scheme | - | Hydrophilic indicator and very suitable for soil conservation | Very high nutrient value for cattle + Handicraft (incense and perfume processing) |

| | | | | | | |
|---|---|---|---|---|---|---|
| | | Terminal stratum) | | | | |
| *T6*<br>*Pterocarpus erinacaceus* | Banni | Sandy low plateau woodland savannah | Range Management Scheme | Peneclimax | Soil Conservation factor | Dry season fodder reserve for cattle |
| *T7.*<br>*Piliosstigma reticulum* | Barkeewi | Low plateau park landscape (permanent Human Settlement indicator) | Settlement associated to local agro forestry | Hydroclimax | Phreatic ground water-table indicator /<br>Land Conservation | Magical and religious symbolism |
| *H3.*<br>*Digitaria Gayana* | Barsabarali | Open bush steppe on stony low plateau | "Bad-lands" | Postclimax | Typical Land Degradation Indicator | (Toxically plant for eye leading to blindness)<br>Magico-religeous symbolism |
| *T8*<br>*Euphorbia balsamifera* | Batakereewi | Old human settlement site (sometimes abandoned) on paleo fallow | Settlement | Anthropoclimax | Very large ecological amplitude plant suitable to land conservation | Human Medicine (Local Chirurgical operation and Dermatology) |
| *H4.*<br>*Andropogon pinguipes* | Bayeewi | Greeward stratum associated To Continental Terminal outcropping | Settlement | Post climax | Land Degradation Indicator | - |
| *H5.*<br>*Cienfuegosa digitata* | Belwelngel | Herbaceous steppe/ sandy plateau grassland | Range Management Schemes | Climax | Phreatic ground water-table indicator very suited to Agro forestry | - |
| *T9*<br>*Sterculia setigera* | Bobori | Sandy plateau woodland savannah (as relic of pluvial phase indicator: old savannah ecosystem) | Range Management scheme | Pre-climax (residual) | Stable geosystem indicator | Human Food (condiments)<br>and Handicraft (gum production) |
| *T10.*<br>*Strophantus sarmentosus* | Bonnji | Grassland savannah along the talwegs | Settlement | Peneclimax | Stable Geosystem Indicator | |
| *T11*<br>*Indigofera oblongifolia* | Baalboru | Floodplain dwarf steppe / shrub | Forestry | Climax | Very suitable for soil structure stabilisation | Handicraft (cloth piece-dyeing in blue -indigo colour) |
| *T12*<br>*Gardina ternifolia* | Boseewi | Ferrous low plateau (Continental Terminal outcropping) steppe | Forestry | - | - | Human Food (could be developed as Plantation) |

| | | | | | | |
|---|---|---|---|---|---|---|
| *T13*<br>*Celtis integrifolia* | Ganki (Buleewi) | Dry<br>Valley levees park landscapes | Settlement/Range Management Scheme | Climax | Stable geosystem Indicator (Suitable to land husbandry for agro forestry schemes) | Excellent dry season fodder |
| *H.6*<br>*Momordica balsamina* | Borbooki | Mainly found in Human Settlement (around and in the compounds or houses) | Human Settlement | Anthropoclimax | - | - |
| *H.7*<br>*Dactyloctenium aegyptium* | Burgel Colel | Sandy low plateau rainy season greensward or short grasslands (Sometimes as recent fallows) | Range Management Schemes | Anthropoclimax | Stable Geosystem / geofacies Indicator | Excellent rainy season fodder |
| *H.8*<br>*Echinocloa stagnina* | Burgu | Floodplain grasslands | Range Management Scheme | Hydroclimax | Stable Geosystem / geofacies Indicator (noteworthy wetlands micro site)) | Excellent dry season fodder |
| *T.14*<br>*Dichrostachy cinera* | Burli | Loamy low plateau steppe | Settlement /Forestry | - | - | |
| *H.9*<br>*Aristida stipoides* | Buudel gaynaako | Sandy<br>low plateau greensward /or open grassland | Range management scheme | Climax | Stable<br>and conserved geosystem | - |
| *H.10*<br>*Alysicarpus ovalifolius* | Mbaamto | Sand - loamy Low plateau talweg greenswards (Abandoned settlement and archaeological sites indicator) | Settlement/<br>Range Management Scheme | Anthropoclimax | Stable<br>geosystem/geofacies Indicator | Excellent rainy season fodder |
| *T15*<br>*Merua angolensis* | Bagu | «Barren Land » out<br>of termitaries collapsing | Bad Land | Pedoclimax in Regressive phase | Completely<br>Degraded Landscapes | - |
| *T16*<br>*Andansonia digitata* | Bokki | Very large ecological amplitude space yielding park landscapes open savannah | Mixed Uses:<br>Agro forestry +<br>Range management | Climax | Both resource conservation and development as natural tree stratum for food crop cultivation and protection | Human Food + Veterinary Medicine applications + Handicraft (cordage and basket making). Magico-religeous symbolism (holy tree for some Fulbe family groups) |

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| *T17*<br>*Acacia seyal* | Bulbi | Loamy low plateau woodland savannah | Range Management Scheme | Climax | - | - |
| *T.18*<br>*Combretum nigricans* | Buski | Loamy low plateau steppe | Forestry | Climax | Stable geosystem / geofacies Indicator | Handicraft (kitchen and milk processing tools fabrication) |
| *T19*<br>*Pterocarpus lucens* | Cani | Continental Terminal outcropping woodland savannah | Range Management Scheme / Forestry | Pedoclimax | Very adapted species to drought and stable geosystem Indicator (typical resource complex); sometimes overexploited as fuel wood) | Housing construction + Energy (fuel wood) |
| *T20*<br>*Leptadenia hastata* | Capatoowi | Shrub or open savannah with large ecological amplitude | Range Management | - | - | Fodder specially for Camels |
| *T21*<br>*.Acacia albida* | Caski | Park landscape linked to permanent human settlement | Human Settlement / Mixed Uses | Anthropoclimax | The most known resource conservation and development balance model development model. An example of integrated mixed farming in Sahel ecosystem and Soil Restoration scheme | Very high value dry season fodder. |
| *T22*<br>*Ficus theophylla* | Dubaleewi (Ceekeewi) | Floodplain tall woodland savannah or / and park landscape linked to ancient human settlement | Human Settlement / Agro forestry | Anthropoclimax | Very suitable for Land Husbandry (soil structure restoration) by geotope cluster reconstitution | Suited for village and small urban centre land use planning and development schemes. Historical symbolism for the local collective memory. |
| *H.11*<br>*Andropogon gayanus* | Ceelal | Sandy low plateau grasslands | Range Management Schemes | Piroclimax (stabilisation from repetitive bush fire) | Retroaction and auto regularization phenomenon Indicator | Rainy season fodder + construction (straw roof adapted protect against to hot and dry temperature) |

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| *T.23*<br>*Acacia radianna* | Ciluki | Woodland savannah with large ecological amplitude linked to ancient human settlement (sometimes archaeological sites indicator) | Human Settlement | Anthropoclimax | Natural soil fertiliser in N, P, K elements, specially for recent fallows land restoration | High value dry season fodder.<br>Important socio-cultural symbolism |
| *T24 Lanea acida* | Cingooli | Sandy-loamy low plateau woodland savannah (water pool woodland belts) | Range Management Scheme/ / Forestry | Pedoclimax | | Fruit crop and could be developed as plantation |
| *T25*<br>*Feretia apodanthera* | Commbi | In isolated termitaries | - | Pedoclimax | Stable micro ecotopes / geotopes | High value fodder +<br>Sacred handicraft (religious symbolism related the bovidae pre-Islamic cult) + Handicraft (aromatic plant for perfume making) |
| *H. 12*<br>*Nymphea lotus* | Daaraame | Watershed grasslands belts around permanent water points | Range Management and Gathering Economy | Hydroclimax | Very stable geofacies Indicator | Dry season fodder and alternative human food (in famine period) |
| *T26*<br>*Adenium obesum* | Daraboggel | Isolated species in poor soil | «Bad-lands» | Postclimax | Land Degradation indicator | Dangerous poison for human and cattle |
| *H.13*<br>*Calocynthus vulgaris* | Deenerol | Cultivated terrain greensward | Agriculture (Food crops) | Agroclimax (agro-system) | Land conservation: wandering dunes stabilisation and fertilisation | Human Food crops<br>(wet green vegetable) |
| *T27*<br>*Loesenerlla africana* | Delbi | Low plateau steppe | Range Management | - | - | Handicraft and construction (resistant wood to termites) |
| *H.14.*<br>*Zornia glochidiata* | Dengo | Ancient fallows greensward related to old settlement or archaeological site | Agriculture and Range Management | Post climax | Land Degradation Indicator | Excellent fodder for sheep and goat +Human food (sauce) + handicraft (soap fabrication) |
| *T28*<br>*Cordilla pinnata* | Duke | Low sandy-loamy plateau dwarf savannah or steppe | Range Management and Forestry | - | - | Handicraft +construction material + Veterinary medicine (cures horse digestive diseases) |
| *T29* | Dooki | Sandy low plateau woodland | Range Management | Climax | Geosystem conservation as | Excellent dry season fodder + Human Medicine |

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| *Combretum glutinosum* | | savannah or pastoral park landscape | Scheme and Forestry | | soil structure stabilisation | (against cold or malaria fever) + Handicraft (for loin clothes dyeing) |
| *T30* *Sclerocarrya birrea* | Eeri | Sandy low plateau woodland savannah | Range Management schemes and Forestry | Climax | Geosystem conservation as soil structure stabilisation | Human Medicine (against snake bite) + dairy work handicraft + magico-religeous symbolism |
| *H15.* *Hibiscus aspera* | Follere | Recent fallows open shrub | Agriculture (Food crops) | Anthropoclimax | - | Human Food and Human Medicine (Drink, spices condiments for sauce, cures the tension) |
| *T31* *Acacia adansonii* | Gawdi | Flood plain woodland savannah | Forestry | Hydro-pedoclimax | Stable geosystem Indicator | Human Medicine (cures syphilis) against vomiting and cures the wounds infections) + Handicraft (animal skin tanny) |
| *T32* *Guiera senegalensis* | Geloki | Sandy low plateau steppe or recent fallow | Range Management Schemes | Climax / or Post climax | Either as stable Geosystem Indicator in pastoral areas or as Land Degradation Indicator in cultivated and abandoned areas | Excellent dry season fodder + magico-religeous symbolism. |
| *T33* *Maytenus senegalensis* | Giyal gooti | Continental Terminal outcropping Barren lands open steppe | Agro forestry | Post-climax | Land Degradation Indicator | Magico-religeous symbolism |
| *T34* *Boscia senegalensis* | Gijili | Continental Terminal outcropping barren lands open steppe | Forestry | Post-climax | Land Degradation Indicator | Excellent human food resource (specially during the famine period) + human medicine (cures digestive sickness) +handicraft (soap fabrication) |
| *L.35* *Balanites aegyptiaca* | Muurtooki (Golteeki) | Ancient fallow and ancient settlement sites woodland savannah or park landscape | Human Settlement + Mixed Uses | Anthropoclimax | Suitable for Land Husbandry (geofacies stabilisation) and as stratum for Agro forestry structure model | Energy (charcoal production) + domestic oil production + Human Medicine (cures Bilharzias disease); could be developed as fruit plantation (food and cash crops) |
| *T36* *Acacia nilotica* | Gonaaki | Flood plain woodland savannah | Range Management Schemes and Forestry | Hydro climax | Very stable geosystem Indicator | Excellent dry season fodder for goat and sheep |
| *T.37* | Guubi | Loamy-sandy low plateau | Forestry | Climax | Phreatic water-table Indicator | Excellent rainy and dry season fodder + |

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| *Acacia Ataxacantha* | | talwegs steppe or open savannah (or Isolated in the termitaries) | | | and stable geosystem. Very suited for soil restoration | Human Medicine (cures Bilharzias disease) |
| *T38*<br>*Lanea humilis* | Humeteewi | Loamy low plateau talwegs steppe or open savannah | Forestry | - | - | Handicraft (incense making) |
| *T.39*<br>*Zizyphus Mauritania* | Jaabi | Ancient fallows / park landscape with very large ecological amplitude | Mixed Uses | Climax | Very high drought resistant and suitable for agro forestry models (in short term land resource planning) | Human Food (could be developed as fruit plantation) + pastoral culture magico-religeous symbolism +Human Medicine (cures stomach sickness and other digestive organs) |
| *T.40*<br>*Dalbergia melanoxylon* | Jalambaani | Low plateau woodland savannah | Forestry | Postclimax | Overexploited and very unstable geosystems | Handicraft (furniture's fabrication, Art Instrument and Drums) |
| *T.41Tamarix indica* | Jammi | Large ecological amplitude Park landscape mainly linked to ancient human settlement | Human Settlement / Agro forestry | Anthropoclimax | Stable Geosystem Indicator | Human Food (tonic drink + condiments /spice) magico-religeous symbolism (spirits of ancestors sites) |
| *T.42*<br>*Bombax costatum* | Jooyi | Large ecological amplitude woodland savannah | Forestry | Paleoclimax (pluvial phase relic) | As Resource Conservation (to be protected at any rate) | Settlement building (houses timbering) + Human Medicine (cures pancratis sickness) |
| *H.16*<br>*Hibiscus esculentus* | Kanje | Leguminous plant associated to cultivated areas | Food Crops/ / Human Settlement | Agroclimax | Cultivar very suitable for land husbandry (biological soil fertiliser) | Excellent Human Food Crops (sauce, flour and paste making) |
| *H17.*<br>*Cenchrus biflorus* | Kebbe | Sandy low plateau grasslands | Range Management Scheme | Climax | Land Resource conservation (biological soil fertiliser). | Early rainy season fodder |
| *T.43*<br>*Heeria insignis* | Keelleli | Sandy low plateau steppe | Range Management Scheme | - | - | Human Medicine (against diarrhoea) + Zoo economy (improves the yield of cow milk) |
| *T.44*<br>*Grewia bicolor* | Kelli | Loamy low plateau open savannah or steppe, often as isolated in termitary | Range Management Schemes / Forestry | Climax | Land resource conservation: suitable species as habitat for fauna and flora (bees and birds) | Human Food (Honey production) pastoral handicraft (milk processing tools) + magico-religeous symbolism |

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| *T.45*<br>*Oxythenanthura abyssinica* | Kewal | Stony low plateau open steppe | Range Management Scheme | Pedoclimax | Land Degradation Hazards Indicator | Construction Handicraft + dry season fodder |
| *T.46.*<br>*Presoptis africana* | Koyi | Sandy low plateau steppe | Forestry | - | - | Excellent construction wood (termites resistant) |
| *T.47*<br>*Anogeisus leiocarpus* | Kojolli | Permanent water pools woodland savannah belts | Forestry | Hydroclimax | Stable geofacies indicator | Construction wood + Human Medicine (against diarrhoea) |
| *H18.*<br>*Cassia abssus* | Korjel | Continental Terminal outcropping greensward | «Bad Land» | Postclimax | Land Degradation Indicator | Human Medicine (cures eyes infections) |
| *T.48*<br>*Mitragyna inermis* | Koyli | Large ecological amplitude woodland belts around the permanent water pools | Forestry | Hydroclimax | Excellent land conservation geofacies as a integrated biodiversity site (all kind of reptile and birds) providing phyplancton and zooplankton for fishes | Handicraft (fishing Instrument making) + magico-religeous symbolism for the ancient agro-halieutic civilization |
| *H.19*<br>*Ctenum newtonii* | Laacel dawaadi | Sandy low plateau grassland | Settlement/ Range Management | penelimax (piroclimax) frequent bushfire | Stable Geosystem Indicator (as stabilized geosystem from bush fire adaptation) | Excellent dry season fodder |
| *T.49*<br>*Combretum aculaetum* | Lawñanndi | Sandy-loamy low plateau woodland savannah | Range Management | - | - | Excellent dry season fodder |
| *H.20*<br>*Merrimia pinnata* | Leebel | Sandy Low plateau dwarf grassland | Range Management Schemes | Climax | Stable geosystem Indicator | Excellent dry season fodder (specially for sheep) |
| *H.21*<br>*Merua oblongifolia* | Lelleli | Continental Terminal outcropping stony low plateau open grassland | Range Management Scheme | Pedoclimax (regressive) | Land Degradation Indicator (suitable to soil erosion) | Excellent rainy season fodder |
| *T.50*<br>*Bauhinia ruficens* | Nammaari | Large ecological amplitude open steppe | Mixed Uses | Anthropoclimax | Phreatic water-table indicator, land resource trends to Land | Excellent fodder for sheep and goat (all seasons) |

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| | | | | | Degradation (overgrazing) | |
| *T51*<br>*Cratera adansonni* | Naiki | Woodland savannah belt around permanent water pools | Range management Scheme | Hydroclimax | Stable geosystem Indicator | Human Food (as alternative during famine period) |
| *T52*<br>*Diospyros mespilliformis* | Nelbi | Loamy low plateau talwegs steppe | Range management Scheme | Climax | Stable geosystem indicator (suitable habitat for birds) | Handicraft (encens / perfumes) + socio-cultural symbolism |
| *H.22*<br>*Cyrtosperma senegalensis* | Walwaalnde | Loamy low plateau talwegs greensward or low grasslands | Human Settlement, Range Management | Anthropoclimax | Auto regularisation degraded geosystem Indicator | Excellent high value fodder (improves qualitatively and quantitatively the sheep and goat yield of milk) |
| *T53*<br>*Strychnos spinosa* | Norwaali | Sandy low plateau steppe | Range Management | Anthropoclimax | Dry season growing plant and suitable for soil structure deep restoration | Excellent dry season fodder |
| *H.23*<br>*Echilochloa stagnina* | Paggiri<br>Jaawle | Loamy low plateau grasslands | Food crops /<br>Range Management | Climax | Suitable for artificial fodder cultivation or mixed farming systems. Agro-pastorals grasslands models within sedentarization context | Human food crops in famine period + excellent rainy season fodder |
| *T54*<br>*Acacia senegal* | Pattuki | Large ecological amplitude woodland savannah (may develop to park landscape) | Forestry | Anthropoclimax | Suitable for geosystem stabilisation (often overexploited) | Human food (sweet food processing) + Handicraft (material tinting).<br>Played a historical role in the Shale and Sahara transcontinental trade |
| *T55*<br>*Hymenocardia acida* | Pellitti | Limited ecological amplitude woodland savannah open steppe | Forestry | - | - | Magico-religeous symbolism |
| *T56*<br>*Terminalia avicenidoides* | Puleemi | Sandy low plateau savannah | Agro forestry | - | - | Human food (food flavouring plant) + Human Medicine (cures stomach diseases) |
| *H.24*<br>*Cassia sieberiena* | Samba Siññiñoowi | Continental Terminal outcropping stony low plateau low grasslands | Forestry | Postclimax | Land Degradation Indicator | Human Medicine (helps easy digestion and against fever) |
| *H.25* | Siiringo (Siwko) | Floodplain | Range management | Hydroclimax | Phreatic water table indicator | Handicraft (incense making and basket fabrication) |

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| *Vetiveria nigritana* | | watershed grassland | Scheme/ / Forestry/ Human Settlement | /Anthropoclimax | and very suitable to soil structure stabilisation | + Human food (for drink water filtering) + housing construction |
| *H.26* *Panicum anabaptisum* | Siiwo | Floodplain watershed grasslands | Range Management Scheme / Human Settlement | Anthropoclimax | Water table indicator and suitable for degraded soils restoration | Dry season fodder + Handicraft (basket making / housing construction |
| *T57* *Jatropha curcas* | Tabanaani | Low plateau park landscapes linked to ancient human settlement or ancient fallows or as archaeological sites indicator | Human settlement/ mixed Uses | Anthropoclimax | Land Degradation indicator | Human Medicine (against wound infections) |
| *T58* *Combretum micrantum* | Talli | Sandy low plateau steppe | Range Management / Forestry | Climax | Suitable for tree stratum for agro forestry land development | Human food and Human Medicine (infusions + cures bilharzias and prostatis) |
| *H.27* *Tribullus terrestris* | Tuppere | Recent fallow greensward | Range Management | Anthropoclimax | Suitable for Nitrogene fixation as natural fertiliser for degraded soils | Early rainy season fodder |
| *H.28* *Crotalaria perrottetig* | Waawre | Sandy low plateau grassland | Range Management | Climax | Stable geosystems Indicator | Excellent dry season fodder |

*1. T = Ligneous tree or shrub *2. H = Herbaceous