THE ESTIMATION OF THE HERBACEOUS BIOMASS IN THE SAHELIANS PASTORAL ZONES USING A GIS

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ABSTRACT
In the Sahel region the pastorals resources are strongly linked to the fluctuation of the biomass production and as well as the breeding systems, which are based on the transhumance and the nomadism as well.
In the present study, an integrated approach of multi-source, multi-type and multi-scales data analysis in the pastoral zone in Senegal, Mali, Burkina Faso, Mauritania, Niger and Chad has been developed using PC-Arc/Info™ and Arc/View™ potentialities for the purpose of Sahelian rangeland production estimation.

INTRODUCTION
Depending of the fragility of the environmental and the socio-economical context in the sahelian zone, the breeding sector plays an important role in the mitigation or the worsing of food crisis.
For hence, the availability of information on pastoral resources is a very important component for food security and a right land management.
The integration of pastoral monitoring in famines and early warning systems started 10 years ago. The experience developed in the present paper has been carried out by the Early Warning and Agricultural Productions Forecast Project (Pj. AP3A) hosted by the AGRHYMET Regional Center in Niamey, Niger, funded by Italian Cooperation and sponsored by the World Meteorological Organization.

The objective is mainly to give an adequate information about rangelands such as inventory fixtures during the main production period, the raining season in the sahelian region. In addition to fields census, data approaches has been developed with remote sensing such as NOAA –AVHRR to model rangeland production with normalized difference vegetation index (Justice and al. 1986). This model based on NDVI has a challenge to estimate a dry matter yield at regional scale over many ecosystems. Although the use of field data is justified, the process takes a considerable amount of time and money especially as on a large scale.
In the Biomass modeling rank, a progress has been done with the P.P.S project (the Sahelian Rangeland Production Project) in Mali, which developed the method based on taking into account the water and nutrients balance for rangeland production estimation. One of the interesting points of the methodology is the global assessment using data over a large working scale surface.
Within the PJ. AP3A objectives, many data have been collected, tabular data as well as numeric coverage data, particularly in the pastoral domain where additional coverages about the sahelian pastoral unit have been digitized using PC-Arc/Info™. The main purpose is to integrate all the data to produce pastoral map risk, which is a real need for regional environment monitoring and national early warning services.
The whole process is built over a territorial system analysis (SAT) and circumstantial system analysis (SAC) within a GIS-based and database system management environment.

STUDY AREA

The permanent Interstate Committee for Drought Control in the Sahel (CILSS) covers nine (9) West African countries, which are the Cape Verde Islands, Senegal, Guinea-Bissau, the Gambia, Mauritania, Mali, Burkina Faso, Niger, Chad (Figure 1). The study area extends from 12° to 18° N and 18° W to 24° E, and covers about 1.050.000 km² over six (6) countries in West Africa. This area corresponds to the pastoral zone in the Sahelian region (CIRAD-IEMVT-CTA 1989) which is delimited by the 150 mm to 600 mm (Hiernaux 1983).The vegetation of the area is composed of semi-desert grassland and grassland with trees and shrubs typical of the Sahelian Zone (Justice et al. 1986). The rainfall distribution is seasonal, occurring between May and October, with a maximum of precipitation in August and a high spatial and temporal variability from one year to another. The production of annual grasses and the floristic composition depend on this variability, which has serious effects on the livelihoods of local pastoral community in the drought years.

Figure 1 – Study area.

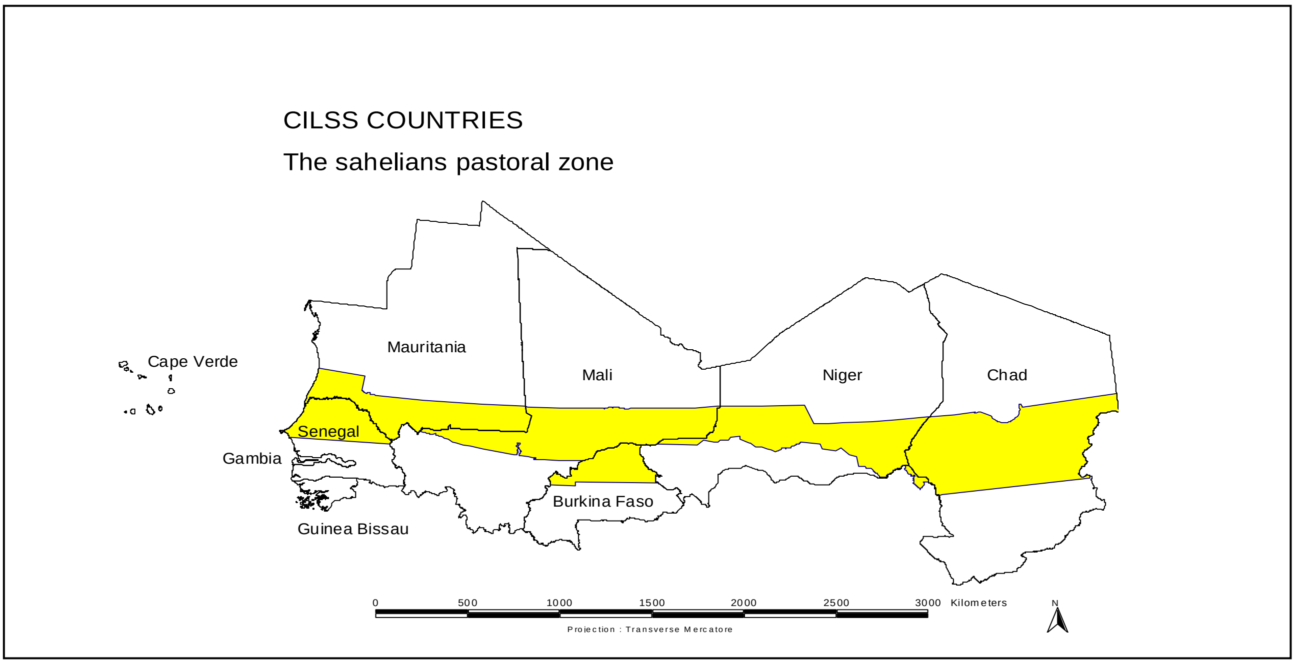
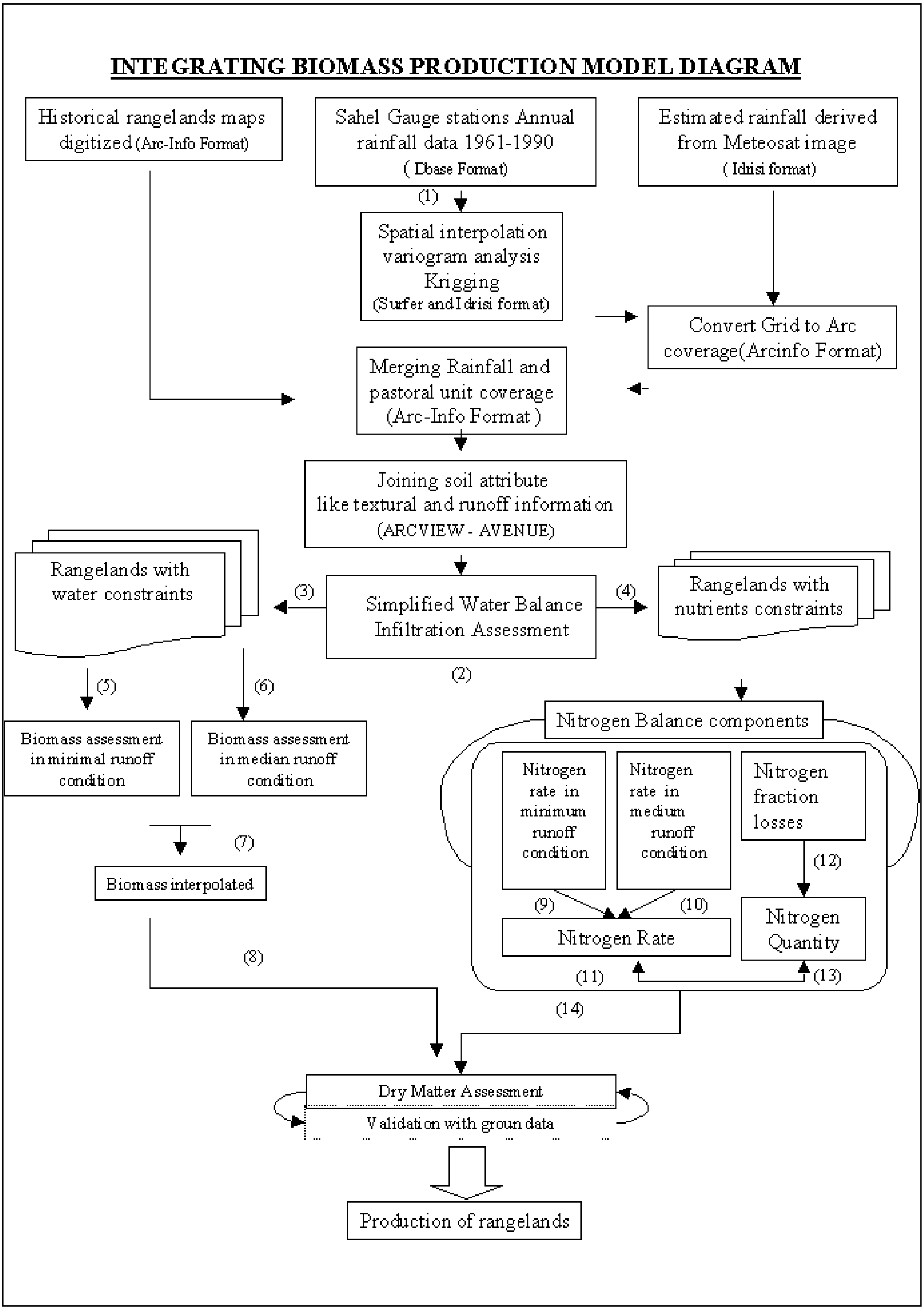


Figure 2 – Model diagram.



GIS APPLICATION

The Biomass production model (figure 2) was developed by the AP3A project in order to give a structural information about different climate conditions and predict as well the potential carrying capacity. The model is now operational and is able to simulate historical data on a yearly basis, assuming that the rainfall data is available.

The model biomass yield computation is based on a simplified water infiltration and nitrogen balance, which are also based on surface runoff. The model-input coverages are the maps of pastoral units (Djaby et al. 1996) and rainfall data. The major output components are the dry matter production map at scale 1km*1km or 5km*5km and the biomass quality based on nitrogen content.

METHODOLOGY

- Model Definition

In the sahelian region, the rangeland production depends primarily on the rainfall below 250 mm and the nutrient components as well above this limit. The availability of water in the soil depends on streaming, infiltration and soils texture. The study region is first divided according to the climatic limit, and an empirical relation found by P.P.S project is applied to compute the biomass yield.

The model requires various data to simulate long-term or annual biomass. Hence, the important data used by the model derives from pastoral units and as well as rainfall data maps. As far as rainfall is concerned, we used either synoptic and secondary national networks raingauge stations data or Meteosat full-resolution images (AGRHYMET 1994).

- GIS Layers

Two PC-Arc/Info™ coverages are required to run the model with an Avenue™ procedure. These are the rainfall and pastoral units maps.

Compiling the rainfall map using meteorological stations data, a variogram analysis has been carried out in order to better interpolate this data value over a region. Indeed, the study shows that the sahelian rainfall is correlated to the latitude. The softwares used for this analysis are Variowin™, Surfer™ and PC-Arc/Info™.

For structural studies in regard with the project objectives, analysis of wet and dry years is carried out to assess pastoral conditions.

Variowin sotware provides parameters such as kriging sill and range. Those parameters are used as input to Surfer™ software to produce an Erdas™ Grid File with Idrisi™ software. The conversion of rainfall grid to a polygon coverage is accomplished using GRIDPOLY command which converts the grid layer into a coverage containing polygons with 1 km x 1km resolution. Using rainfall derived from Meteosat follows the same step to produce PC-Arc/Info™ coverage.

The pastoral units are digitized from ATLAS-IEMVT maps at 1:500.000 scale (De Filippis et al. 1996). Each unit of map has his texture. Hence, a table containing for each unit, the texture, the historical data for biomass yield and the geo-morphological characteristics is created.

Those two layers, rainfall and pastoral units maps are used to create new arc coverage by using PC-Arc/Info™ command INTERSECT. Each pastoral unit is cut into segments with rainfall polygons and encoded with respective rainfall covers ids .

For run the model, Avenue's scripts are written to make a step by step computation of all parameters. In addition, a customised menu with those scripts is developed.

- Link soils parameteres

In Arc-View™, in addition to the new coverage created in the last step, soils parameters, derived from pastoral maps are linked to the coverage with pastoral unit ids for each country map.

The source of soil information derives from pastoral maps. An assimilation with six types of soils which have a runoff coefficient under differents climatics zones allows to compute each sub-pastoral units infiltration (Breman and Nico de Ridder, 1991). For each pastoral unit, soils are assumed uniformly distributed. Three components are identified, sandy soils, shallow detritic soils and fluviatile soils. Sandy soils are deep, homogeneous and of eolic origin. Detriic soils are developed on laterite or sandstone. Fluviatile soils are deep, clayey soils, or loamy-clayey subsoils covered with sandy-loamy topsoil (Penning de Vries, 1986).

- Assessment of water belance

Water balance is a complex phenomena which depend on runoff, infiltration, intensity and rainfall duration, soils characteristics and vegetation cover. Those items vary considerably from one area to another. With the global context of this assessment, the water balance is resumed by infiltration. The infiltrated quantity is done by corrected rainfall with water stream near the surface. The infiltrated quantity is equals to the amount of rainfall.

- Assessment of the biomass yield below 250 mm rainfall

Between the biomass and then rainfall, the relation is not direct, but depends on soil characteristics. Two relations are defined to compute these parameters. First, the biomass yield is computed from conditions where runoff is very low, and second, under the medium condition. Interpolations give the result in a condition of combined pastoral and rainfall unit.

- Assessment of the biomass yield above 250 mm rainfall

The process here is based on nitrogen assessment. The Nitrogen Balance assumption is that the actual amount of N in Vegetation, plus inorganic N in the soil during the growing season, reflects the sum of all processes, including uptake (Penning de Vries et M. Djitèye, 1982). Considering the equilibrium situation, the amount of N, which enters the system, is equal to the amount that leaves it. In the model, annual fraction of N lost by the system is computed. It is a function of rainfall. Also, the fraction of the N contained in the biomass at flowering is computed with the rate of N in the biomass at different condition of runoff.

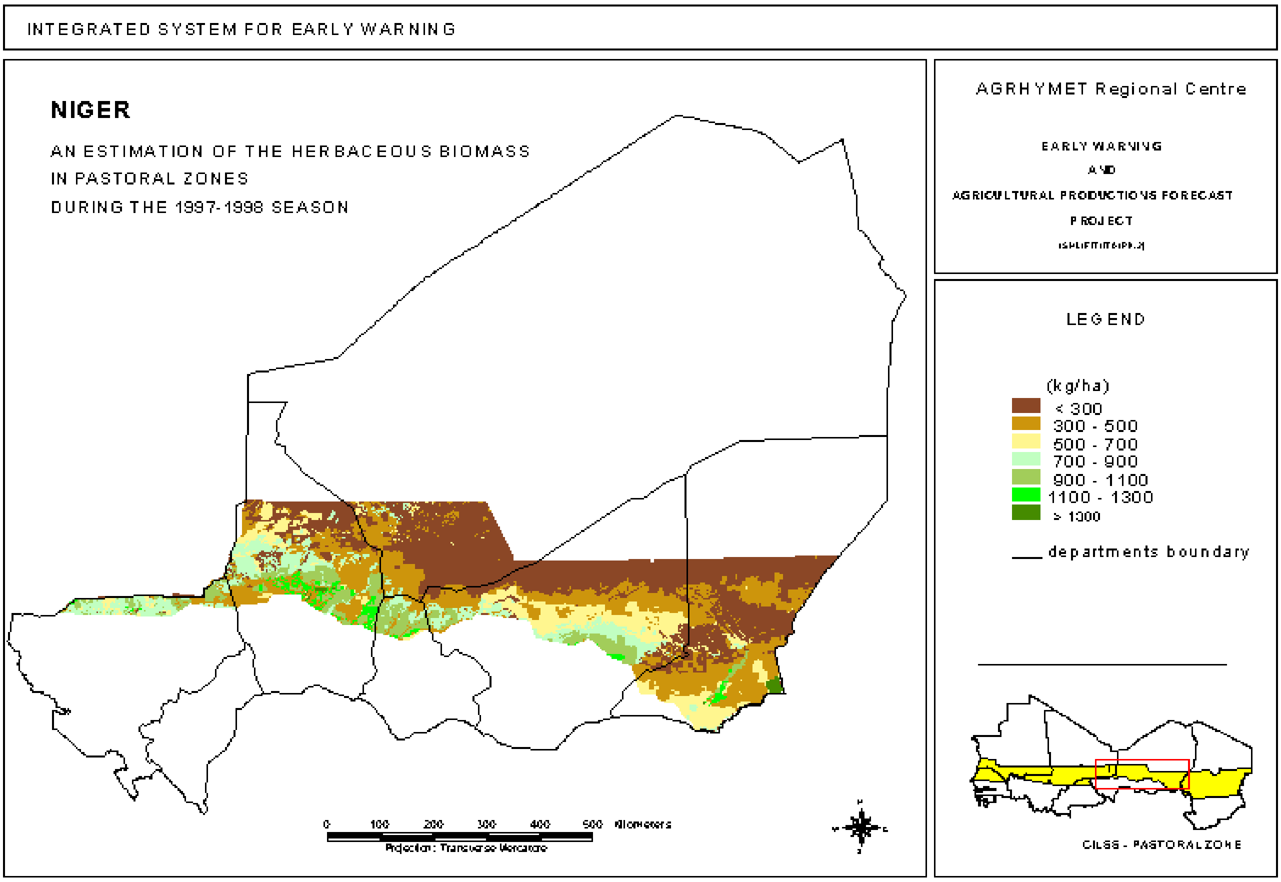
- Assessment of the biomass in flood zone

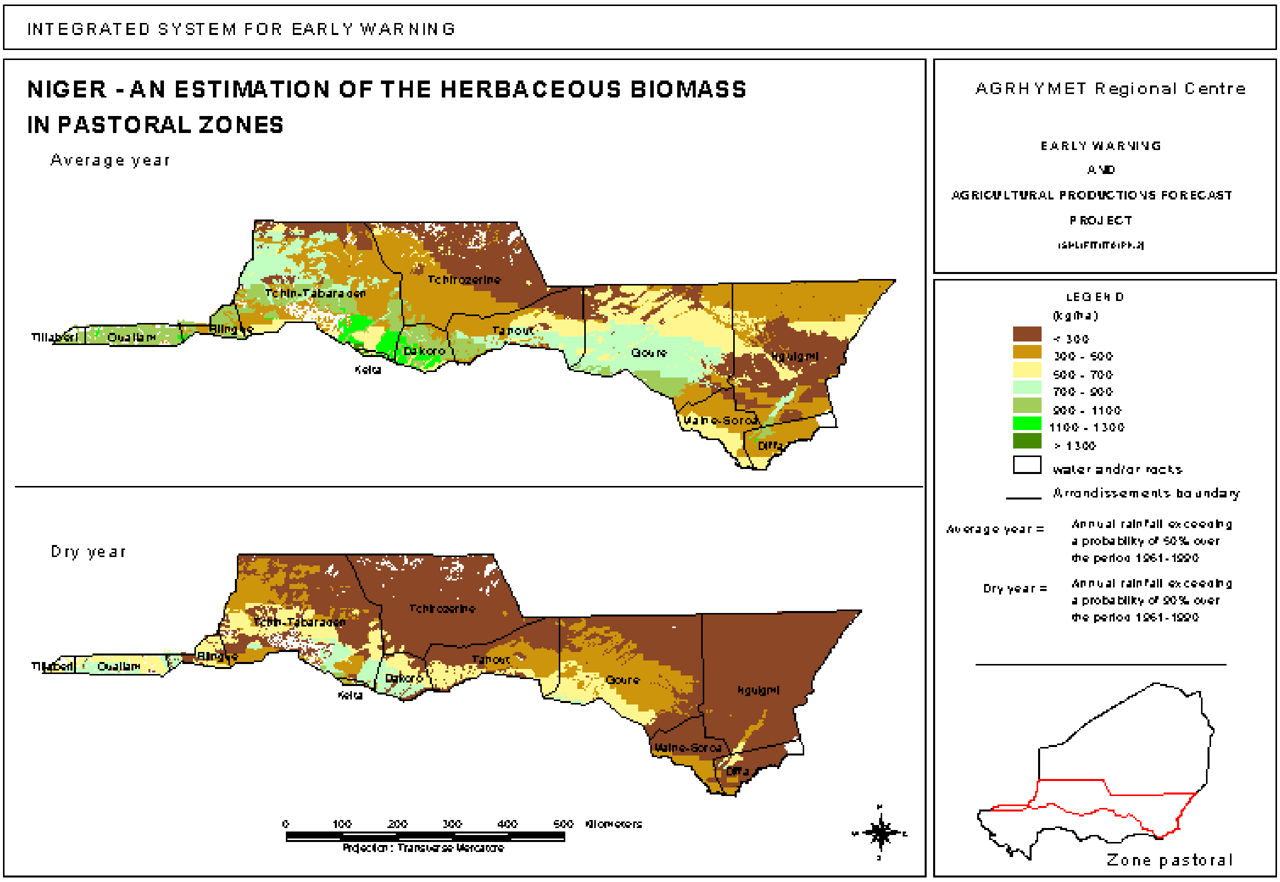
In flood zones, the cycle of vegetation depends of water supplied by river. Information does not exist any more in this zone. Within a pastoral study undertaken by IEMVT, historical data can be found. Considering that those zones have the same type of soils, biomass are computed like other zones and corrected with a coefficient derived from historical data.

RESULTS

The main results obtained are the biomass yield in each component, pastoral unit crossed by rainfall data and forage quality (figure 3 and 4). The data could cover many or one year. With the rainfall historical data, model could produce a long-term reference. The extend of the result, although limited can be developed for administrative level or bio-climatic levels.

Figure 3 and 4 – Estimation of herbaceus biomass by GIS application.





The comparison with historical data or ground data provided by national services shows a good accuracy of dry matter. So the method results in an output closed to the assessment using the NDVI. The difference occurs in the precision due to soil differences, which are taken into an account in the later methodology.
Automating the computation with ArcView™ is a good approach to disseminate the methodology, hence users could change parameters, such as rainfall and runoff.

CONCLUSIONS

Using PC-Arc/Info™ and ArcView™ allows implementing a rough assessment of dry matter in Gis for early warning purpose. This approach produces results that can contribute to identifying a vulnerable zone where carrying capacity is very low during one year, or in extreme drought conditions. Another important issue is the possibility to use grid data such as estimated rainfall data provided by Meteosat to substitute for ground data, for the biomass assessment in October, a month over which data are not gathered.
However, the approach has a limit that does not take into account the floristic diversity and the land-use. So, the challenge of the future is to implement a brief period assessment that uses decadal rainfall data as well as a more accurate topographic zone.

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