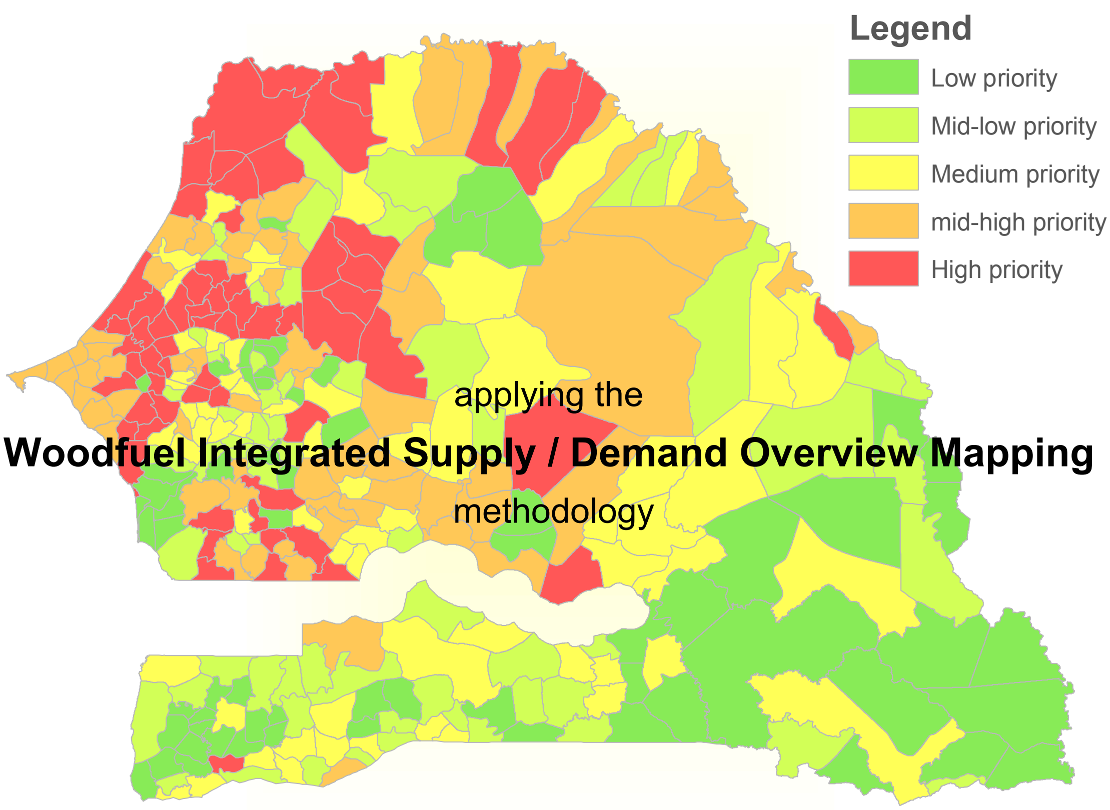
WISDOM

Senegal

Analysis of woodfuel production-consumption patterns in Senegal



applying the

Woodfuel Integrated Supply / Demand Overview Mapping

methodology

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

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Acronyms

WISDOM	Woodfuels Integrated Supply / Demand Overview Mapping
CSE	*Centre de Suivi Ecologique* of Dakar
CR	*Communautè Rurale* (Rural Community)
SenWEM	Senegal Wood Energy Map
GPL	Liquefied Petroleum Gas (LPG)
ABF/DE	*Association Bois de Feu* (French NGO)/ *Direction de l'Energie*
PSACD	*Projet Sénégalo-Allemand Combustibles Domestiques*
SEMIS/DE	*Service de l'Energie en Milieu Sahélien* / *Direction de l'Energie*
PJ	Petajoules
EROS/USGS	EROS Data Center of the United States Geological Survey
DAT	Direction de l'Aménagement du Territoire
USAID	United States Development Assistance Programme
FRA	Forest Resources Assessment Programme of FAO.
PROGEDE	*Programme de Gestion Durable et Participative des Energies Traditionnelles et de Substitution*
FAO	Food and Agriculture Organization of the United Nations
WETT99BE	"Best Estimates" of the FAO WETT study "The Role of Wood Energy in Africa" based on available sources (S. Amous' 1999)
FAOSTAT	FAO Forest Product s Yearbook database (2004).
GFPOS	FAO's Global Forest Products Outlook Study
IEA	International Energy Agency
ESMAP	Energy Sector Management Assistance Programme (World Bank / UNDP).
ENDA/IEPE	Environment and Development Action (International NGO, Senegal) and I*nstitute d'Economie et de Politique de l'Energie* (Grenoble).
RPTES	Regional Programme on Traditional Energy Systems (World Bank)

Introduction

Background

A key activity of FAO Wood Energy Programme is the preparation and dissemination of planning tools aimed to support the formulation of sound wood energy policies.

One of the main tools to be used is **WISDOM** (**Woodfuels Integrated Supply / Demand Overview Mapping**), which was developed by FAO Wood Energy Programme in collaboration with the National Autonomous University of Mexico (Masera, Drigo, Trossero, 2003)[1]. It is a methodological approach used for the geographical representation of woodfuel consumption and supply sources of a specific area to assess the woodfuel sustainability aspects and issues. Based on the analysis of the information collected from these exercises, it can be selected where, what and how main interventions are needed and strategically plan main activities to be undertaken.

WISDOM has been applied in Mexico and Slovenia. Senegal is the country selected for the first African case study to be undertaken, in the current phase, as a desk study. The Centre de Suivie Ecologique of Dakar (CSE) provided the main information for its realization.

The study was carried out in the framework of FAO Wood Energy Programme with support and supervision of the Forest Product Service (FOPP) of the Forest Products and Economics Division.

Woodfuels Integrated Supply / Demand Overview Mapping (WISDOM)

WISDOM is a spatially-explicit method oriented to support strategic wood energy planning and policy formulation, through the integration and analysis of existing woodfuels demand and supply related information and indicators. Rather than absolute and quantitative data, WISDOM is meant to provide relative/qualitative values such as risk zoning or criticality ranking, highlighting, at the highest possible spatial detail, the areas deserving attention and, if needed, additional data collection. In other words, WISDOM serves as an ASSESSING and STRATEGIC PLANNING tool to identify priority places for action.

WISDOM is based on: a) the use of geo-referenced socio-demographic and natural resource databases integrated within a geographical information system; b) a minimum spatial unit of analysis at sub-national level; c) a modular, open, and adaptable framework which integrates information of relevance to wood energy from multiple sources; and d) a comprehensive coverage of woodfuel resources and demand.

The use of WISDOM involves five main steps:

1. Definition of the spatial unit of analysis.
2. Development of the DEMAND module.
3. Development of the SUPPLY module.
4. Development of the INTEGRATION module.
5. Selection of the PRIORITY areas.

Objectives of the study

In line with the above, the main scope of the present desk-study was to carry out a first-level analysis of Senegal's woodfuels consumption/production patterns based on the information provided by the Centre de Suivie Ecologique (CSE), integrated by other information from available documentation and web sources, and within a timeframe of four weeks.

The objective of this study was to design and implement a WISDOM case study for Senegal based on the existing available information and, more specifically:

- to review, harmonize and integrate, at the level of Communautè Rurale (CR), the available information related to production and consumption of fuelwood and charcoal;
- to review possible scenarios to the 2010 horizon;
- to develop a spatially-explicit representation of woodfuel production-consumption patterns in Senegal in ArcGis environment;
- to summarize the main results, findings, conclusions and recommendations, as appropriate, including topics requiring further in-depth studies.

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[1] Document accessible at http://www.fao.org/DOCREP/005/Y4719E/Y4719E00.HTM

Main results

Senegal Wood Energy Map (SenWEM)

The main result of the study is the **WISDOM Geodatabase**, which is a spatially-discreet wood energy information system. The WISDOM Geodatabase developed in this study contains all variables relevant to the wood energy sectors that could be so far assembled and/or estimated, associated with the most discreet territorial subdivision. The WISDOM geodatabase was used as the basis of the **Senegal Wood Energy Map (SenWEM)**, which allows a consistent and holistic vision of fuelwood and charcoal demand and supply parameters and their spatial relation over the temporal window 1990-2010.

The WISDOM Geodatabase contains numerous parameters and map attributes associated to the selected sub-national level of analysis. These parameters and map attributes, which are discussed in greater detail in the subsequent sections, may be grouped in the following four categories:

Administrative elements: code and name of 321 Commaunetés Rurales (CR), 96 Arrondissements, 31 Departements and 10 Regions. The geodatabase includes also the new territorial structure established after year 2002. The analysis, however, was conducted with the earlier structure since all demographic and socioeconomic parameters referred to it.

Demand-related variables: Urban and rural population data by CR and 1990 – 2010 time series. Saturation of fuelwood, charcoal and GPL by urban and rural users and by Region and estimated per-capita consumption rates. Socioeconomic parameters (access to drinking water, health services, market, roads and school) for 13000 villages and summarized by CR; other socioeconomic parameters at Department level. Time series of household urban and rural consumption 1990-2010 by CR were developed, according to two different scenarios:

A) 1996 consumption pattern (Semis survey) projected using urban/rural population growth rates;

B) 1996 consumption pattern projected using urban/rural population growth rates and 1992-1996 consumption trends (comparison of ABF/DE 1992 and Semis 1996).

Supply-related variables: Senegal vegetation map (based on USAID/DAT 1982) with stocking and productivity for each of the 30 classes of the map (derived from PSACD 1998); map of Senegal Protected areas with 5 categories; road network and distribution of 13000 villages; 3km buffer around roads and villages; estimated exploitable fraction of wood resources according to protection categories and distance from roads and villages. Time series of wood stocking and productivity (total and accessible fraction) by CR according to two change scenarios:

EROS = stocking and productivity reduced in time according to the land use change estimated by EROS/USGS – CSE over the period 1965 – 2000 (Tappan et al, 2003);

FRA = stocking and productivity reduced in time according to the forest area change estimated by FAO FRA 2000 (FAO 2001).

Derived Supply/Demand variables: Time series (1990-2010) of balance between household fuelwood and charcoal consumptions (scenarios A and B) and total/accessible wood resources (scenarios EROS and FRA). The balance analysis represents the first level of integration of supply and demand variables and the original SenWEM contribution.

The present paper has the scope of highlighting the main issues that were disclosed during the execution of the study and of summarizing/documenting the activities undertaken. It must be emphasized that the true result of the study is the WISDOM geostatistical database developed in the process, which provides spatially-discreet representations that in this report cannot be fully rendered.

Findings

The information available for the study, partly provided by CSE and partly derived from literature and web sites, referred uniquely to the household sector. As a consequence, the commercial and industrial uses are not covered by this study. Although it is widely accepted that the majority of woodfuel consumption in Senegal is absorbed by the household sector [11] [13], it is important to expand the dataset and the analysis to the other sectors as soon as adequate information become available.

Another important aspect is that the essential databases were all rather out of date: population projections were still based on the 1988 census (the results of the 2003 census not being released as yet); the last national survey of woodfuels consumption was dated 1996; vegetation data and associated stocking and productivity referred to a data set produced in 1982. Although the time series of consumption and potential production produced for this study tried to keep pace with the changes on the basis of best available references, it would be important to review results and assumptions as soon as new relevant data become available.

Woodfuels demand

One of the main issues highlighted by the study concerns the changes in household woodfuels consumption patterns in urban and rural areas. The two more recent national consumption surveys (ABF/DE 1992 and SEMIS/DE 1996 [11]) indicate a significant shift of rural users from fuelwood to charcoal, while the consumption of fuelwood and charcoal in urban areas reduced in favor of GPL. Annex 3 shows the summary results of the two surveys and the apparent consumption trends.

In order to highlight the potential effects of changing consumption patterns, two different scenarios were assumed in the present study:

- a “static” scenario (A) which used the 1996 consumption pattern and projected the consumption using exclusively urban/rural population growth rates;
- a “dynamic” scenario (B) which also used the 1996 pattern but projected the consumption according to the 1992-1996 trends and to population growth rates.

Figures 1 and 2 show the spatial pattern of household fuels consumption (charcoal, fuelwood and GPL) at the level of Rural Communities at reference year (1996, SEMIS/DE survey) and at year 2010, according to scenarios A and B.

Annex 4 shows the consumption scenarios at regional level, from which it appears that the main elements that characterize scenario B are the rapid decrease of woodfuels consumption in the Dakar region and the marked increase of charcoal consumption in all other regions, led by Saint Louis and Thiès.

Projecting the four-year trends (1992-1996) over the subsequent 14-years period may prove unrealistic, and therefore the situation shown by scenario B may exaggerate a certain tendency. On the other hand, it is unlikely that the pattern of consumption remains the same. The shift to GPL and the reduction of woodfuels in urban areas is generally well documented and accepted [4], [9], [13]. What is more critical and probably more questionable, is the shift in rural areas from fuelwood to charcoal, although it may be well justified in consideration of the growth of rural villages and of the decrease of fuelwood gathering due to the increasing distance from wood resources.

Quantitatively, the real situation may be somewhere in between the two scenarios here represented. However, it should be emphasized the main scope of the WISDOM is not to quantify with precision the consumption (especially if the reference data is weak) but rather to highlight possible evolutions that require planners’ attention and to identify priority areas within the country.

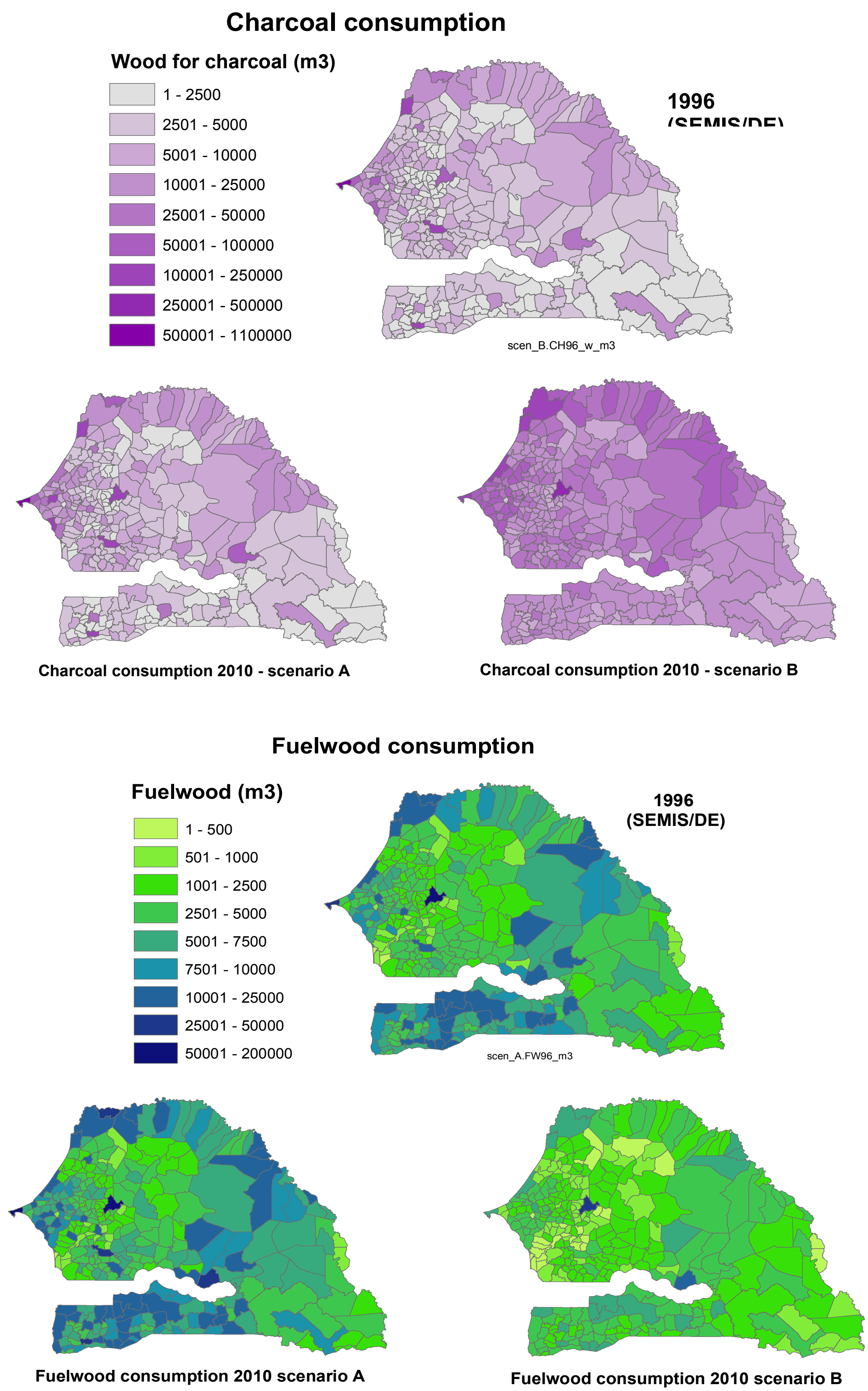


Figure 1: Charcoal and fuelwood consumptions at reference date (1996) and at year 2010 according to scenarios A and B.

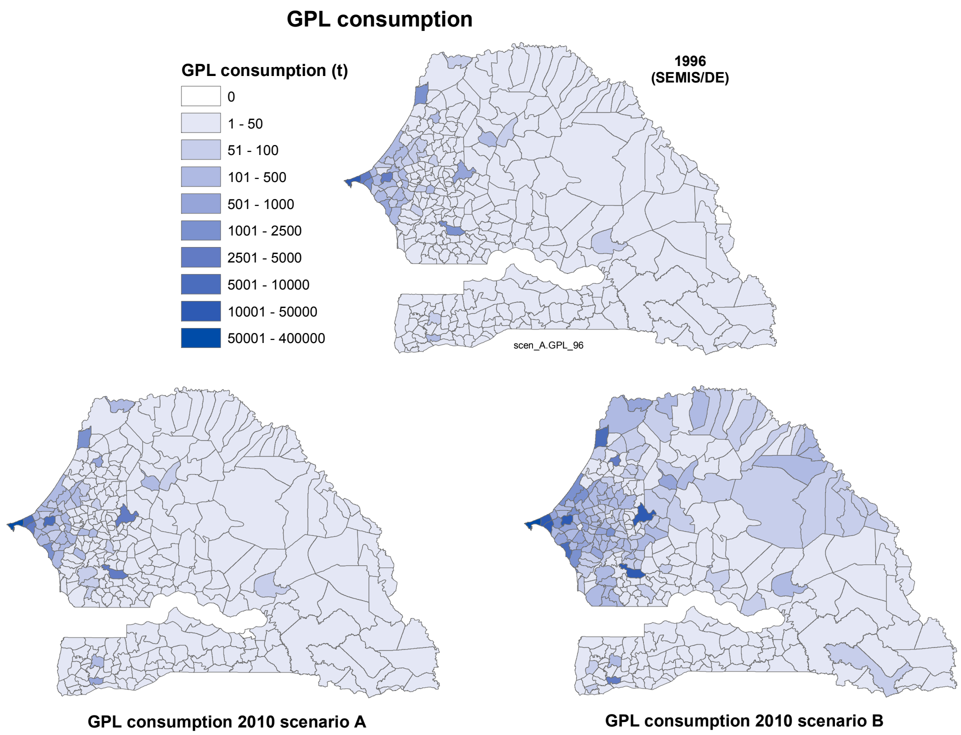


Figure 2: GPL consumption at reference date (1996) and at year 2010 according to scenarios A and B.

Relation with international databases

The estimated consumption of fuelwood and charcoal varies considerably among the various national and international sources. The Wood Energy Information System maintained by the FAO Wood Energy Programme reports the estimated consumption according to leading national and international sources and allows a comfortable comparison. The graphs in Figure 3 show the range of estimates according to main international sources[2].

The aggregated woodfuels consumption estimates from the present study are in line with the lower group of sources (ESMAP, ENDA/IEPE, WETT99BE, Other National), especially considering that the WISDOM estimates refer to the household sector only, not including an additional 10-15 percent for commercial and industrial uses. This group agrees on lower fuelwood consumption and higher charcoal consumption, as can be seen in the graphs in the two lower graphs.

The main difference seems to rest not so much on the total amount of wood energy but rather on the behavior of fuelwood and charcoal consumptions. The two lower graphs in Figure 3 highlight the

[2] Sources:

WETT99BE "Best Estimates" of the FAO WETT study based on available sources (S. Amous' 1999)

FAOSTAT FAO Forest Product s Yearbook database (2004).

GFPOS FAO's Global Forest Products Outlook Study

IEA International Energy Agency. Data on charcoal only.

ESMAP Energy Sector Management Assistance Programme (World Bank / UNDP).

ENDA/IEPE Environment and Development Action (International NGO, Senegal) and Institute d'Economie et de Politique de l'Energie (Grenoble).

Other National Review of Policies in the traditional energy Sector (RPTES) – Country Report for Senegal, 1995 and other national sources.

discrepancies between scenario A, which foresees a steady increase of fuelwood consumption (in line with most pre-‘95 national sources) and scenario B, which sees on the contrary a reduction of fuelwood use in favor of and increasing use of charcoal.

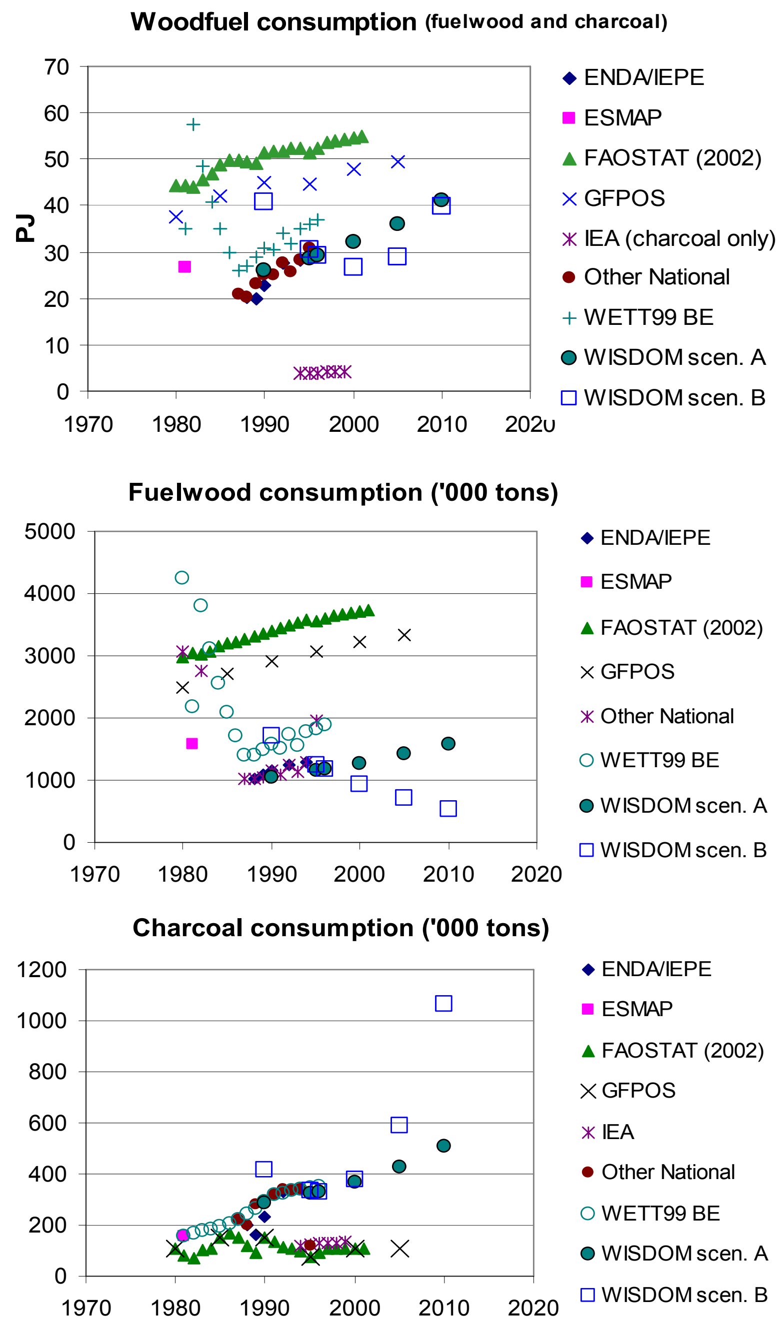


Figure 3: Consumption of woodfuels according to various international sources and to scenarios A and B. Total woodfuels (in PJ), fuelwood and charcoal (in ‘000 tons).

Woodfuels supply

The estimation of sustainable wood resources for energy purposes was based on the 1982 DAT/USAID vegetation map [3] and associated stocking and productivity values [10],[11]. The original total productivity was then projected to year 2010 on account of:

- rates of change of forest and wooded lands for which two different references were used [6] [12], which are described in Annex 6;
- physical/legal accessibility, and
- amount of wood annually needed for other uses (Annex 7).

Figure 4 shows the distribution of wood resources available for energy use by Rural Communities.

Accessible wood for energy

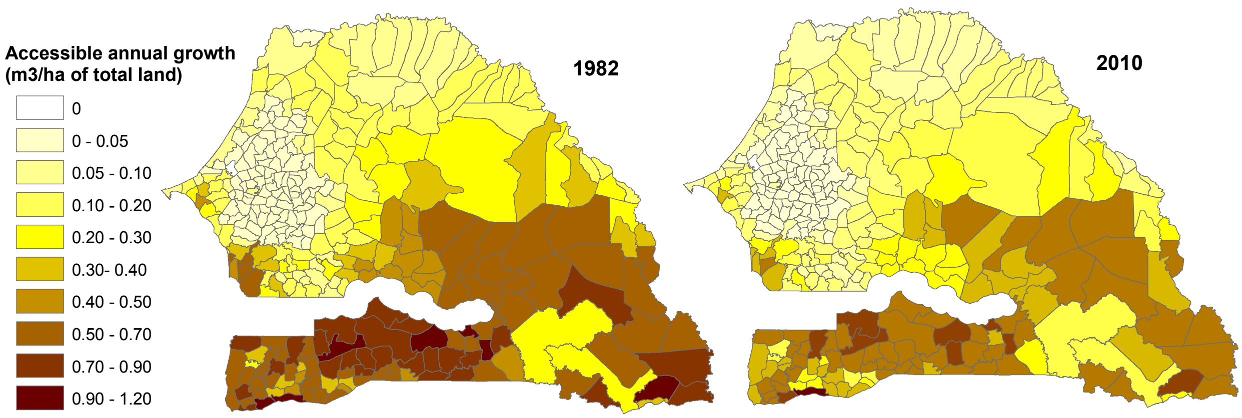


Figure 4: Estimated accessible wood resources at year 1982 (reference date) and year 2010 (applying the FRA2000 deforestation rate).

Supply/demand balance

If the consumption trend hypothesized in scenario B will be confirmed, the pressure on wood resources will, at first, decrease slightly, as effect of the reduced urban demand for charcoal and fuelwood, especially in the Dakar region, and then will rapidly increase to the level of seriously threatening the country's natural wood resources, as effect of the increased demand for charcoal in rural villages.

Up to recent years, over 80 percent of national charcoal production was for the Dakar market and the quasi-totality of charcoal production was concentrated in few areas of Tambacounda and Kolda regions [4]. This constituted a *filiere* somewhat easy to control, if not properly manage.

Now, if the trends assumed in scenario B are real, one of the important effects of the changing consumption patterns is the likely spreading of charcoal production to respond to a more diffuse local demand. This may cause a sudden increase of charcoal-making in areas previously undisturbed (at least for this specific use), making the pressure on local wood resources more ubiquitous and more difficult to control and manage. In this sense, a more "local" production-consumption balance may become a more effective approach of analysis also for charcoal and not only for fuelwood. Figure 5 shows the balance, at year 2010, between the estimated production capacity and the projected woodfuels consumption according to the "dynamic" scenario for each Rural Community of Senegal.

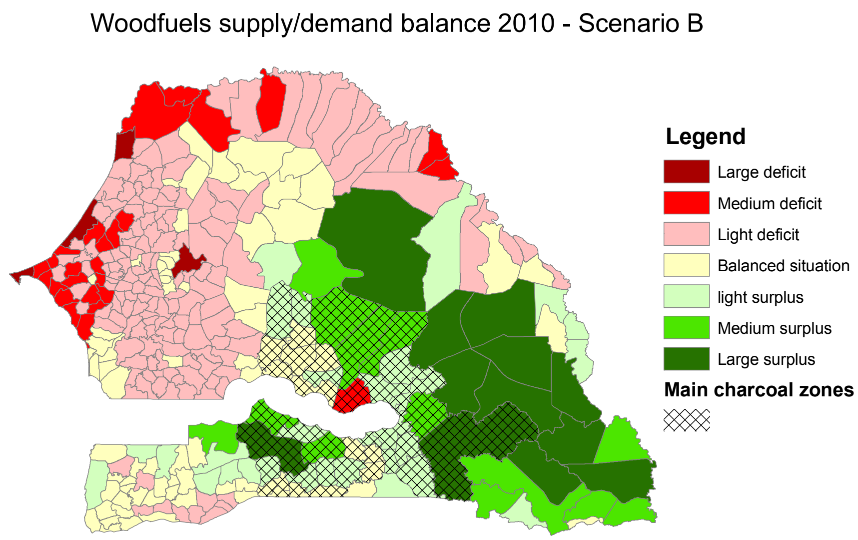


Figure 5: 2010 balance of household woodfuel consumption (fuelwood and wood-for-charcoal) and estimated sustainable productivity (scenario B); also shown are the "traditional" charcoal production areas.

The map depicts a projection, assuming that only local wood is used for both fuelwood and charcoal. Obviously, this is rarely a true condition, especially for charcoal that, as mentioned above, may travel long distances between the production and consumption sites. Nevertheless, if scenario B is realistic the situation may arise in which a growing charcoal market in rural villages gives origin to small local charcoal-making industries and a consequent increase of pressure on local wood resources previously used exclusively as sources of fuelwood. Charcoal making may become more submerse than it was in the recent past, and therefore be characterized by low carbonization efficiencies and even less attention to the sustainability of production. Moreover, this new pressure may concentrate on the northern part of the country, where drier conditions prevail and the ecosystems are even more fragile.

In any case, an important scope of this study is to indicate the zones of the country that are likely to develop critical situations, either in terms of costly supply or in terms of serious unsustainable pressure on natural wood resources.

The time series of national level balances between consumption and estimated sustainable productivity according to scenarios A and B are shown in Figure 6.

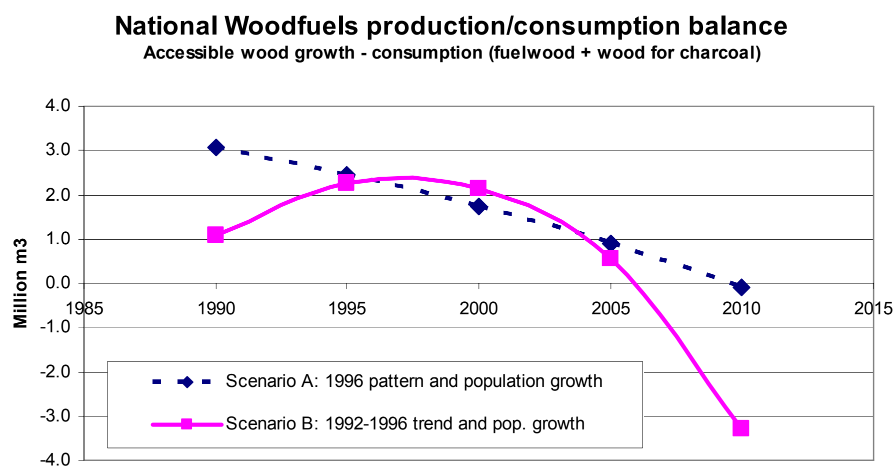


Figure 6: National-level balance of household woodfuel demand (consumption of fuelwood and wood-for-charcoal) and supply (estimated sustainable productivity) according to two consumption scenarios.

Priority zones

The set of indicators produced by CSE in it's study on rural poverty was integrated and combined with woodfuels demand and supply parameters to create an overall preliminary Woodfuels Priority Index (WPI). WPI was developed using several indices based on the possible levels of consumption at year 2010, on the consequent local supply/demand balance and on socioeconomic parameters that represent the poverty level (CSE poverty index). The range of values of each element was ranked in 5 priority levels, from high to low. The three indices were then combined to form an aggregated index, which was eventually ranked again into 5 priority levels. Figure 7 shows the result of this process, highlighting the Rural Communities that deserve particular attention in view of their combined levels of consumption and balance (according to scenario B) and of access to basic social services and infrastructures, defined by the CSE's poverty index.

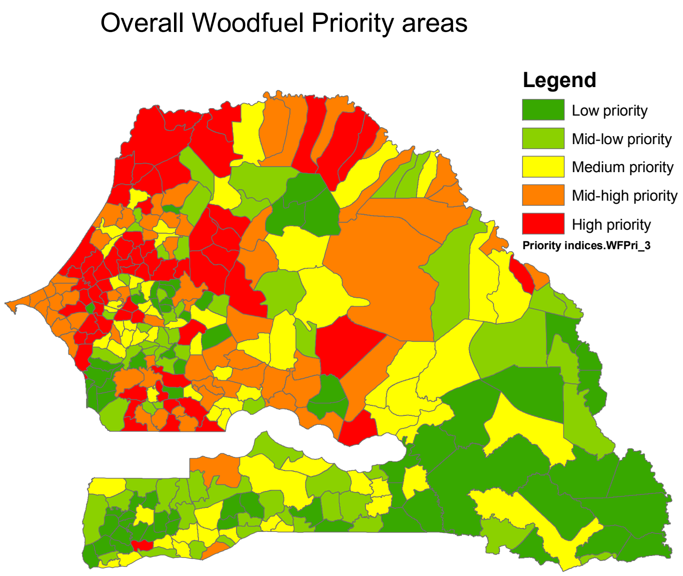


Figure 7: Overall Woodfuel Priority areas based on possible 2010 charcoal consumption (scenario B), production/consumption balance (including fuelwood and charcoal) and on CSE Poverty index.

WISDOM modules

The application of the WISDOM methodology for the development of the Senegal Wood Energy Map (SenWEM) has followed the following five steps:

1. Definition of the spatial unit of analysis.
2. Development of the DEMAND module.
3. Development of the SUPPLY module.
4. Development of the INTEGRATION module.
5. Selection of the PRIORITY areas.

As result, the current version of SenWEM contains numerous parameters and map attributes associated to the selected sub-national level of analysis. These parameters and map attributes, which are discussed in greater detail in the subsequent sections, may be grouped in the following four categories:

Spatial base

The spatial base used for the study is the digital map of Communautés Rurales (CR - rural communities), composed by 321 units. The territorial structure was changed in 2002 with the introduction of one new Region. However, the study was based on the earlier layout, since all available variables referred to that layout. A relation was anyway established between the old and the new layout and therefore it is possible now to convert the results of the study onto the new 2002 territorial structure. Figure 8 shows the distribution of CR and the hierarchy of Arrondissements (92), Departements (30) and Regions (10).

Additional layers used are road network (8 categories) and the distribution of rural villages (13211 villages).

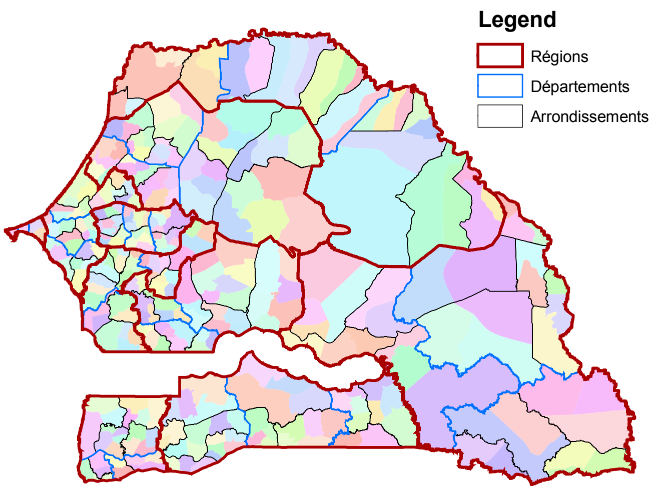


Figure 8: Senegal administrative structure (pre-2002). The color shades represent the Communautés Rurales

DEMAND module

The analysis of woodfuels demand was limited to household consumptions, as no information was available on industrial and commercial wodfuels utilizations. It is widely recognized that the household sector absorbs by the large majority of woodfuels used in Senegal. Thiam, 1995, estimated the non-household uses, such as industry, commerce, transport, handicrafts, agriculture, fishing and services, total some 20 percent of total fuelwood consumption and 10 percent of total charcoal consumption.

Household consumption

The geodatabase of household consumption was developed from the following data sets

Digital maps:

- DEMOCR.shp (provided the estimation of rural population at year 2001 by CR)
- SENCOM.shp (provided the estimation of urban population of 68 urban centers at year 1988 and 2000)

Statistical data:

- PSACD regional, rural, urban population projections 88,90,2000,2010
- Survey ABF/DE 1992 (Association Bois de Feu [French NGO]/Direction de l'Energie), which provided regional estimates of fuelwood, charcoal and GPL for rural and urban areas and for the main cities.
- Survey SEMIS/DE 1996 = Etude sur les énergie domestiques au Sénégal. Service de l'Energie en Milieu Sahélien/ Ministère de l'énergie, des mines et de l'industrie, Direction de l'Energie), which reported on fuelwood, charcoal and GPL consumption at rural and urban areas and for main cities of each region. The survey produced also saturation values for the same three household fuels.
- Survey PSACD 1998 (Projet Sénégalo-Allemand Combustibles Domestiques. Kaolack only)

The results of SEMIS '96 study of household energy, were taken as the main reference. Only exception was the capital of Kaolack Region, which was surveyed by PSACD in 1998. The regional values were then distributed at CR level using rural pop data from CR map and the user saturation values.

Two different scenarios were assumed while developing the consumption time series:

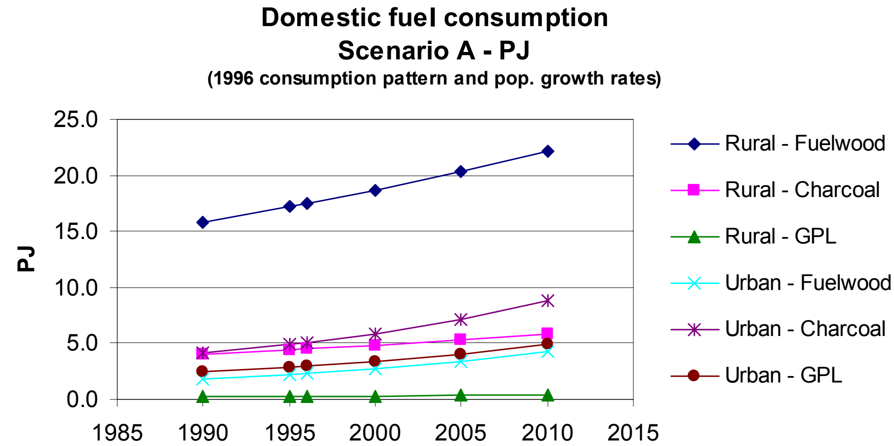
The first (scenario A) used the SEMIS 1996 consumption pattern and projected the values for each CR according to rural and urban population growth estimates. Scenario A should be considered as "control", since it assumed no change in the respective role of the three fuels: fuelwood, charcoal and GPL.

The second scenario (scenario B) used the SEMIS 1996 consumption pattern as starting point and projected the values for each CR according to rural and urban population growth estimates and to the trend observed by comparing the results of ABF/DE 1992 and SEMIS 1996. Scenario B assumed a transition in the role of the three fuels, which produced a dramatically different situation.

Annex 3 reports the national-level results of ABF/DE 1992 and SEMIS/DE 1996 and the resulting consumption trends.

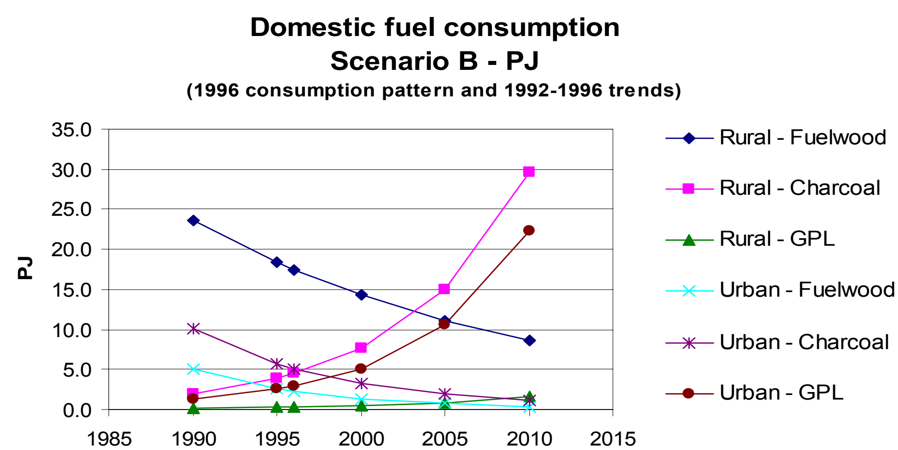
The time series resulting from the two scenarios, in terms of national fuelwood, charcoal and GPL consumption in energy units are shown in figures 9 and 10 and associated tables. The marked difference between the "control" situation of scenario A and the "dynamic" situation of scenario B is due to the reduction of rural fuelwood consumption, replaced by a rapidly increasing rural charcoal consumption, and the reduced use of fuelwood and charcoal in urban areas, in favor of a rapidly increasing use of GPL..

The Graph and table in Figure 11 shows the summary result of the two scenarios in terms of total wood consumption (fuelwood + wood consumed for charcoal production). The curves of the two scenarios cross at year 1996, where both report the consumption levels determined by the Semis 1996 survey. This graph shows well the total demand for wood for household use and the consequent level of pressure on the wood resources of the Country.



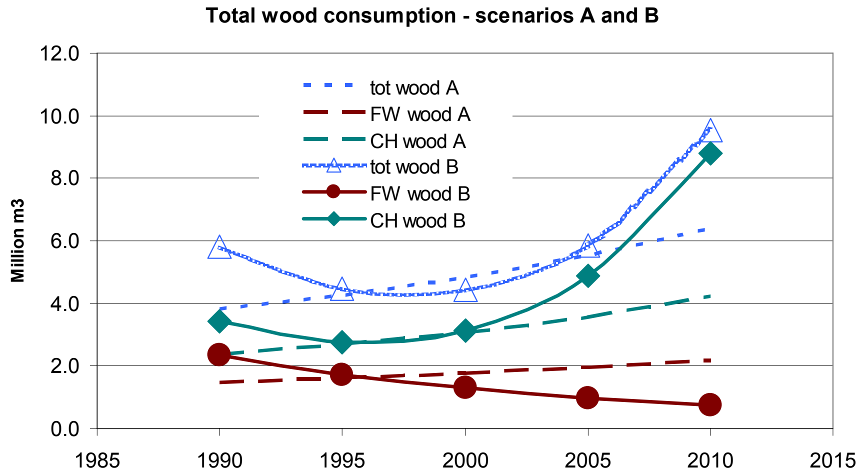
PJ – Scenario A	1990	1995	1996	2000	2005	2010
Rural - Fuelwood	15.8	17.2	17.5	18.6	20.3	22.1
Rural - Charcoal	4.0	4.4	4.5	4.8	5.3	5.8
Rural - GPL	0.3	0.3	0.3	0.3	0.4	0.4
Urban - Fuelwood	1.8	2.2	2.3	2.7	3.4	4.3
Urban - Charcoal	4.2	4.9	5.1	5.9	7.1	8.9
Urban - GPL	2.5	2.9	2.9	3.3	4.0	5.0

Figure 9: Time series of rural and urban household fuels consumption at national level. Scenario A, based on 1996 consumption pattern and population growth rates.



PJ – Scenario B	1990	1995	1996	2000	2005	2010
Rural - Fuelwood	23.6	18.4	17.5	14.3	11.1	8.7
Rural - Charcoal	2.0	3.9	4.5	7.7	15.1	29.6
Rural - GPL	0.1	0.3	0.3	0.5	0.9	1.6
Urban - Fuelwood	5.0	2.6	2.3	1.4	0.7	0.4
Urban - Charcoal	10.0	5.7	5.1	3.3	1.9	1.2
Urban - GPL	1.3	2.6	2.9	5.1	10.5	22.3

Figure 10: Time series of rural and urban household fuels consumption at national level. Scenario B, based on 1996 consumption pattern, 1992-1996 trends and population growth rates.



Million m^3	1990	1995	2000	2005	2010
Scenario A					
FW wood	1.5	1.6	1.8	1.9	2.2
Wood for Charcoal	2.4	2.7	3.1	3.6	4.2
Total wood	**3.8**	**4.3**	**4.8**	**5.5**	**6.4**
Scenario B					
Fuelwood	2.4	1.7	1.3	1.0	0.7
Wood for Charcoal	3.4	2.8	3.1	4.9	8.8
Total wood	**5.8**	**4.5**	**4.4**	**5.8**	**9.6**

Figure 11: National time series of wood consumption for household energy use. Scenarios A and B.

Another important aspect of scenario B is the decentralization of charcoal consumption, which is becoming the dominant woodfuel as well as wood product. As show in the series of graphs in Annex 3, the consumption of wood for energy decreases rapidly in the Dakar region and increases in all other regions, led by Thiés and Saint Louis.

SUPPLY module

The geodatabase of woodfuels production was developed from the following data sets

Digital maps:

- CSE carte de l'occupation des sols (images 1999);
- *Carte du couvert végétal* (DAT/USAID, 1985)
- Villages
- Road network
- Land use Maps of Kolde and Tambacunda 1999-2001 (PROGEDE-SIEF)

Statistical data:

- PSACD 1998, which reported estimated values of wood stocking and productivity for 43 land use classes of the original DAT/USAID vegetation map, based on the work of Piot et al. 1991.
- USGS/EROS Data Center / CSE 2003 study on land cover trends in Senegal
- FAO FRA 2000 forest change estimates.

The CSE land use map is recent but not yet validated and therefore not cleared by CSE. The DAT/USAID map (Figure 12) is rather old but it's in general well accepted (PSACD 1998, Niang and Souleymane, 2002) and the productivity of its classes (Piot 1991) reported by PSACD appear well documented. Moreover, the confusion matrix resulting from the intersection of the two maps with the recent land use maps of Tamba and Kolda, which may be considered as "true reference", indicate that the DAT/USAID holds reasonably well while the CSE land use map needs further analysis.

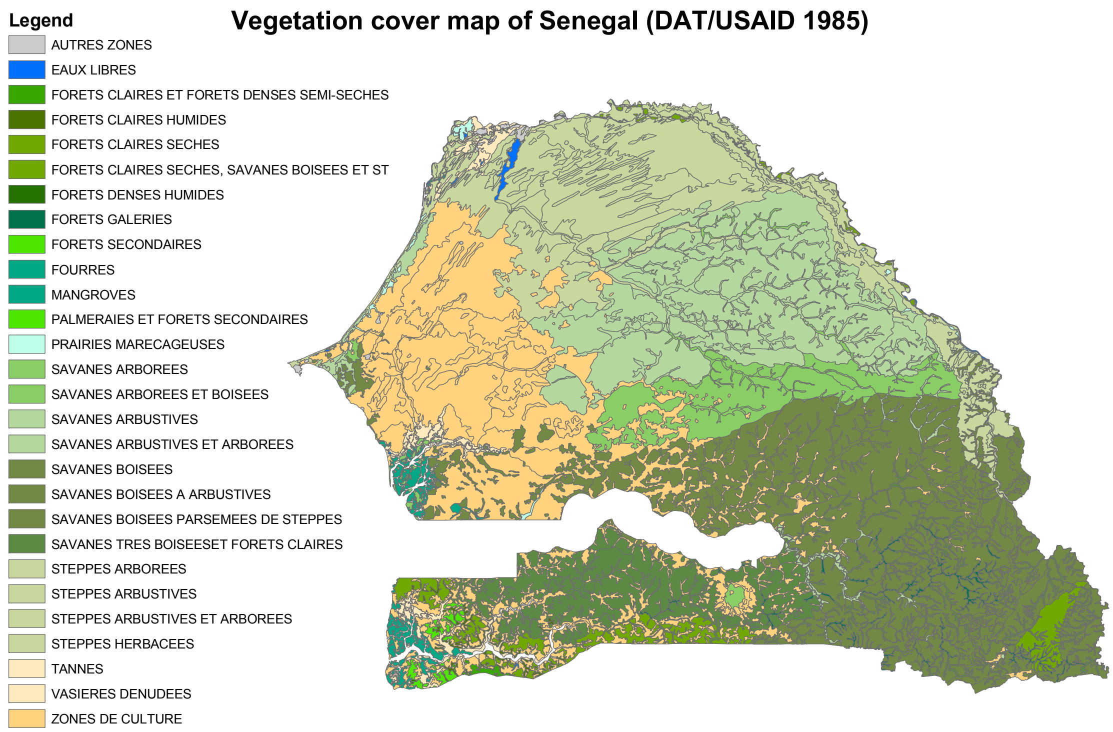


Figure 12: Vegetation map of Senegal (DAT/USAID 1985).

In consideration of these aspects the DAT/USAID map was selected as main support for the development of the Supply Module and for the allocation of biomass resources at CR level. The map was based on Landsat satellite data, aerial photos and field reconnaissance carried out in 1982-1984. The reference date of the information reported in the map was 1982.

The USAID map was then intersected with the administrative map of Senegal to produce land cover classes by Rural Communities at year 1982.

Wood stocking and productivity

The estimation of wood stocking and productivity by CR was based on the statistics reported by PSACD [11] with reference to Piot, 1991 [10], which provided estimated wood stocking and annual productivity for 43 land use classes. The available version of the USAID map didn't match exactly the classes for which PSACD reported volume estimates. The map had 30 classes that probably represent an aggregated version of the original map. The problem was resolved creating a look-up table of correspondence between the map and PSACD data on the basis of class definitions and surface covered (for which PSACD reported also Department-wise statistics). Subsequently, stocking and productivity per hectare assigned to the USAID classes were weighted on the areas of the PSACD sub-classes. The value of stocking and productivity by formation are reported in Annex 5. Stocking and productivity was then estimated for each land cover class of each Rural Community.

Land cover change

The USAID vegetation map, dated 1982, describes a situation that has certainly changed over time. Two different references were used to estimate the changes of wood resources that occurred since the map was produced:

- FAO FRA Forest Resources Assessment 2000 [6], Which provides forest area change estimates for the period 1985 – 2000 ;
- The study carried out by USGS/EROS Data Center and CSE [12]. Tappan et al. (2003) estimated land use changes over the period 1965 – 2000.

The study carried out in the framework of PROGEDE in the regions of Tambacounda and Kolda was also used to assess the change occurred in these areas. Although the comparison between the PROGEDE areas and the USAID map was rather complex, due to the different classifications adopted, it seems that the rates of change estimated by the two national studies above was reasonably validated. Annex 6 briefly describes the data provided by these studies. Annex 5 lists the resulting rates of change by formation.

The rates of change estimated by FRA and by USGS/EROS/CSE were than used to adjust the stocking and productivity of each land cover class of Rural Communities to produce the time series 1982 – 2010, as shown, aggregated at national level, in Figures 13 and 14.

Senegal -time series of total wood stocking

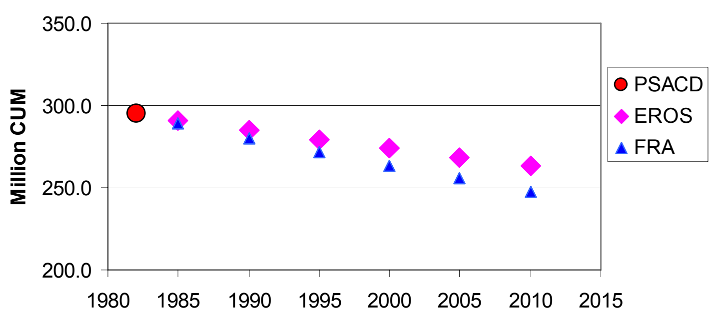


Figure 13: Estimated change of national wood stocking over the period 1982 – 2010.

Senegal - time series of annual growth

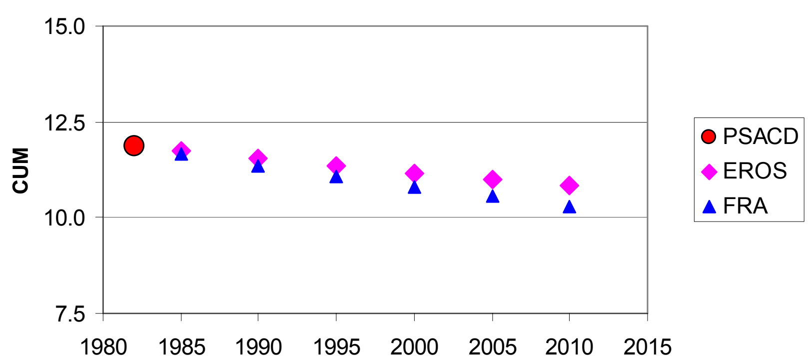


Figure 14: Estimated change of annual wood growth over the period 1982 – 2010.

Accessibility

The accessibility of wood stocking and productivity was estimated by defining areas of "reduced access" according to a 3 km-buffer around roads and villages and protected areas (Figure 15).

Annex 7 provides the reduction rates applied in the study to assess the exploitable volumes according to the assumed categories of accessibility due to distance from roads and villages and to levels of protection.

Annex 8 provides the attributes of total and accessible stocking and productivity associated at each Rural Community and the total values at national level.

It should be noted that, in respect of all other digital maps provided by CSE, the available version of the USAID vegetation map presented a small geometric distortion. This non-systematic distortion was rather negligible for most of the country except in the southeastern regions, where it reached a shift oh up to 1500 m. The geometry of this map could not be corrected in the framework of this study. As consequence, the vegetation classes (from USAID map) and road buffers present in these southern regions a certain error. It is therefore recommended to acquire a geometrically corrected (and possible up to date) map of vegetation and review the distribution of wood resources by accessibility zones.

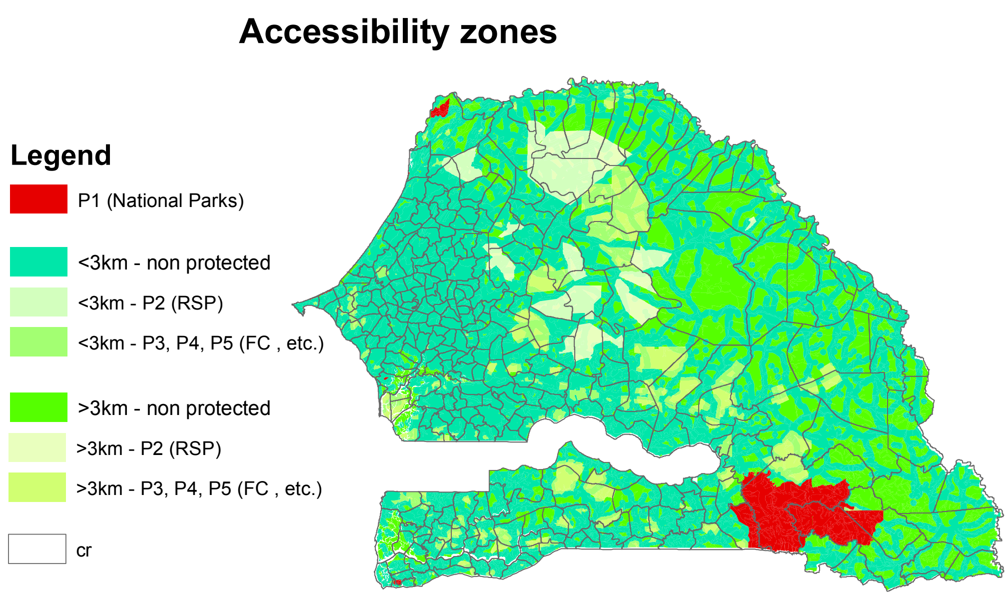


Figure 15: Accessibility zones according to distance from roads and settlements and to categories of protected areas.

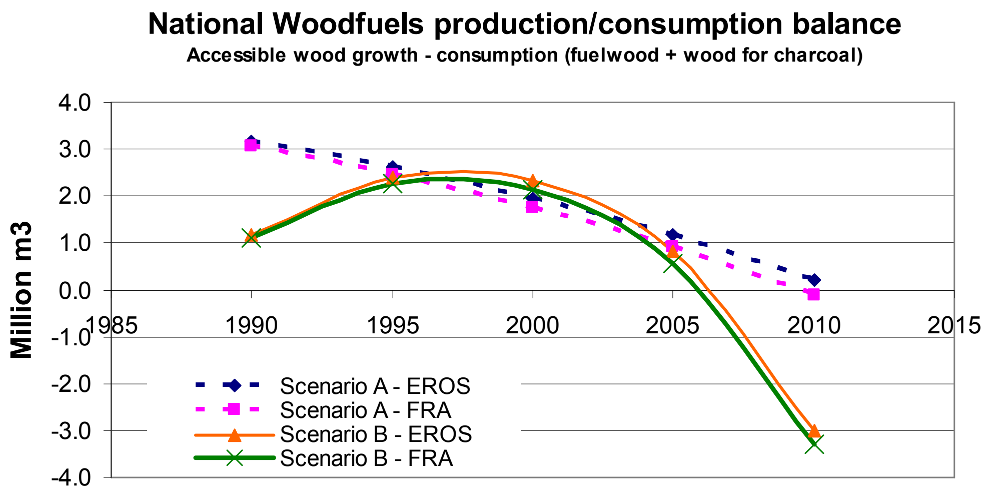
INTEGRATION Module

Supply-Demand balance

The first level of integration was done combining the estimated consumption time series with the estimated accessible productivity at the level of Rural Communities.

The graph and table in Figure 16 shows the estimated national-level balance of wood consumed as fuelwood and for charcoal production, according to consumption scenarios A and B, and the accessible productivity according to the FRA and EROS change scenarios. As evident from the graph, there is little difference between the FRA and EROS change hypothesis. More relevant appear the effect of the two consumption scenarios, with the dynamic scenario B, which assumes a steady increase of charcoal consumption in rural areas, threatening a serious negative balance by year 2010.

The situation at the level of Rural Community is shown in Figures 17, 18 and 19, which show the situation at year 1996, reference year for consumption estimates (common point for both consumption scenarios), and at year 2010, where the two scenarios show marked differences.



Million m^3	1990	1995	2,000	2,005	2,010
Scenario A - EROS	**3.18**	**2.61**	**1.95**	**1.17**	**0.20**
Scenario A - FRA	**3.08**	**2.46**	**1.75**	**0.91**	**-0.11**
Scenario B - EROS	**1.19**	**2.40**	**2.34**	**0.82**	**-2.99**
Scenario B - FRA	**1.10**	**2.25**	**2.14**	**0.56**	**-3.30**

National balances =
accessible wood growth – wood consumption (fuelwood + wood used for charcoal) for household energy.

Figure 16: Time series of national woodfuels production/consumption balances according to consumption scenarios and EROS/FRA change rates.

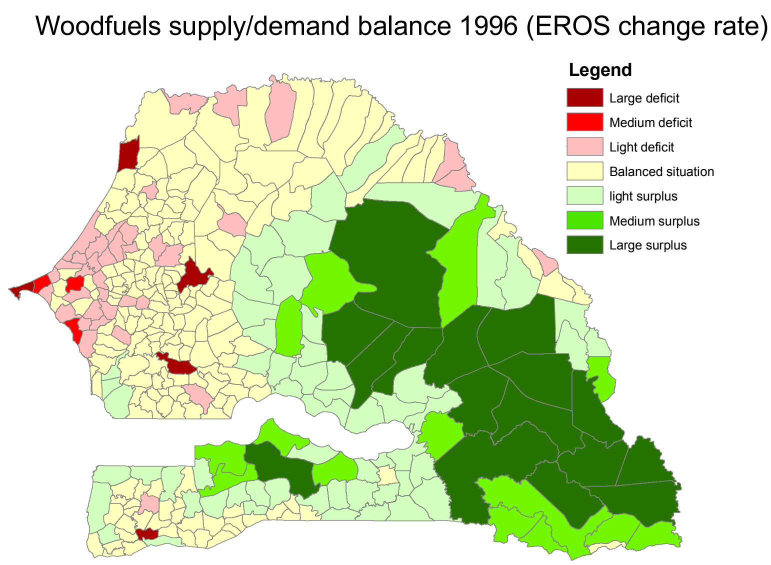


Figure 17: Rural Community level balance at year 1995. Consumption scenario B.

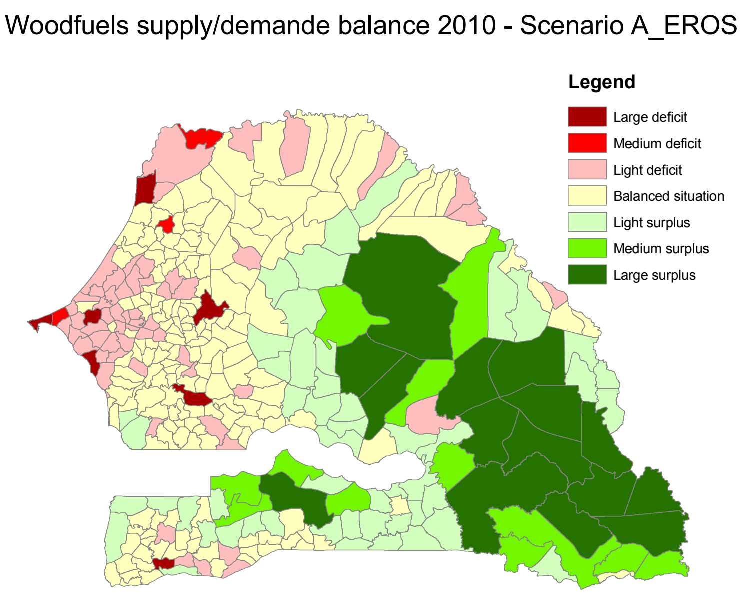


Figure 18: Rural Community level balance at year 2010. Consumption scenario A.

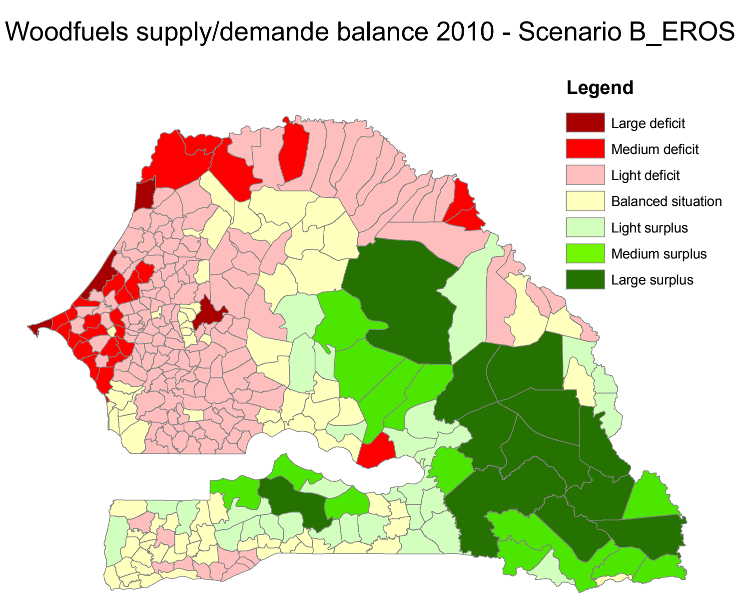


Figure 19: Rural Community level balance at year 2010. Consumption scenario B.

Other socio-economic parameters

The CSE study on rural poverty produced a set of simple indicators based on the estimated access of rural population to social services and infrastructures [2]. The parameters, which were developed for over 13000 villages, were then aggregated by Rural Communities

The following elements were considered:

- Access to a motorable road. This parameter was recreated on the basis of the available maps of villages and road network. A buffer of 3 km from the roads was applied.

- Access to drinking water within 1 km.
- Access to primary school within 3 km.
- Access to health services within 5 km.
- Access to commercial units (shops, market) within the village

Priority index

A simple Woodfuel Priority Index (WPI) was developed using several indices, for each Rural Community, based on three main elements:

- the possible levels of charcoal consumption at year 2010 according to scenario B,
- the local balance between total demand of wood for energy (fuelwood and wood for charcoal) and the estimated accessible and exploitable wood growth;
- socioeconomic parameters that represent the poverty level (CSE poverty index).

The range of values of each element was ranked in 5 priority levels, from high to low. The three indices were then combined to form an aggregated index, as follows:

$$WPI_j = \sum_1^3 I_i * P_i$$

where,

FPI_j = woodfuel priority index for each Rural Community “j”

Ii = index for each of the 3 variable used in the analysis, ranging from 1 to 5.

p_j = weights, set to 1 in this case.

The resulting WPI was also ranked into 5 priority levels. Figure 20 shows the result of this process, highlighting the Rural Communities that deserve particular attention in view of their combined levels of consumption and balance (according to scenario B) and of their limited access to basic social services and infrastructures, defined by the CSE’s poverty index.

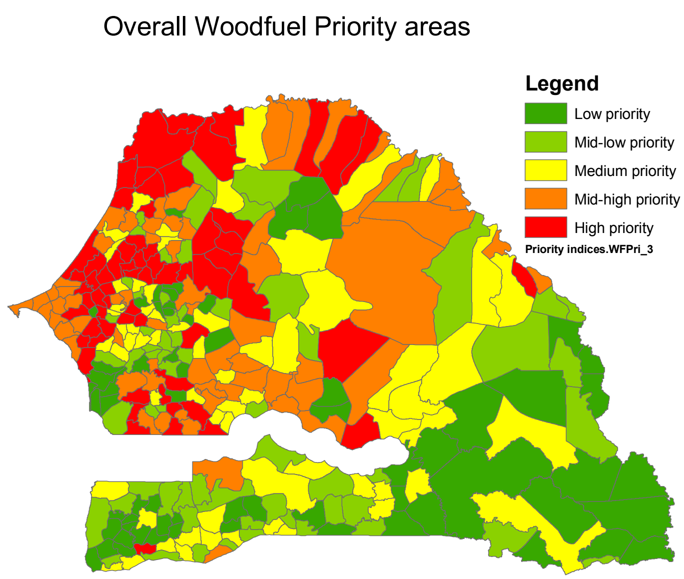


Figure 20: Overall Woodfuel Priority areas based on possible 2010 charcoal consumption (scenario B), production/consumption balance (including fuelwood and charcoal) and on CSE Poverty index.

Conclusions

The current SenWEM version provides a first overview of the main aspects, and spatial pattern, of woodfuels consumption and potential production capacities. However, the following two constraints should be noted:

- the available woodfuels consumption data referred exclusively to the household sector;
- most of the datasets on which it was based were rather outdated, which implied rather long projections to come to today's situation, not to mention future scenarios.

Given these, it is recommended that the results of SenWEM and its geodatabase are reviewed/validated by forestry and energy experts familiar with the Senegal wood energy context and renewed by up-to-date consumption and production information.

Nevertheless, in spite of the above constraints, the exercise proved very effective in providing a coherent and holistic representation of the likely woodfuels demand and supply patterns in Senegal.

As result from this exercise, it is evident that the aspect deserving maximum attention by forestry and energy planners is the evolution of consumption patterns in rural areas and, specifically, the shift from fuelwood to charcoal. The main risk associated to this trend being the possible degradation of forests and wooded lands due to the likely proliferation of uncontrolled and illegal charcoal making.

Even if the specific hypotheses assumed in this study prove unrealistic, due to the reference data used, the possibility to visualize different scenarios integrating data from different sectors and disciplines is itself a major achievement. The possibility to review data belonging to the forestry and energy sector in a uniform context is in fact a qualifying feature of the WISDOM methodology and SenWEM, in its efforts to aggregate consistent demand and supply estimates, combined and harmonized forestry and energy data, offering an important basis for inter-sectoral discussion. In doing this, this case study helped to favor the dialogue and synergies among the wide range of stakeholders of the wood energy sector, and particularly forestry and energy agencies, which is one of the main objectives of the FAO Wood Energy Programme.

Proposed Follow-up action

As for any analytical process, the strength of the SenWEM depends on the quality, completeness and representativity of input data. The need for up-to-date information is particularly evident in this case: the last available census dates back at 1988; the vegetation map dates back at 1982 and the last national consumption survey was carried out in 1996.

In order to strengthen SenWEM and to develop it further, the following activities are proposed:

Demand module:

- Acquire the new population statistics from the Census 2003, which should soon be released. This will allow replacing the rural and urban population projections by Rural Communities with true values. Along with simple demographic statistics, it is hoped that the new census will provide information on social, cultural and economic aspects that will support the development of woodfuels users' profiles and better understand consumption dynamics.
- Collect and integrate information on commercial and industrial uses of woodfuels in rural and urban areas.
- Collect up-to-date information on household consumption with the specific scope of verifying the trend in rural charcoal consumption.

Supply module:

- Verify and validate the recent CSE map of land use because the need for a new vegetation map of the Country is particularly urgent. (In the meanwhile, and as a minimum, the DAT/USAID map should be geometrically corrected to eliminate the slight shift that affects its south-eastern regions).

- Review wood stocking and productivity with reference to the new vegetation/land use map using field data wherever available (eg.: PROGEDE inventory results).

It is therefore recommended to review the WISDOM Geodatabase and SenWEM as soon as consistent new data become available.

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Annex 1: Information matrix

		Spatial / admin. resolution									
		true spatial	Village 2002	CR2002	**Communautes Rurales**	Arro2002	Arrondissement	Comune	Departements	Region	National
	# units	cont.	13211	322	321	96?	92?	67?	31(?)	10	1
Digital map			points	poly	poly	poly	poly	points	poly	poly	
Demography	Tot pop								x	x+PSACD	x
	Rur pop		x		x				(x)	(x)+PSACD	x
	Urb pop							x	x	x+PSACD	x
	Evolution popul.							partial (76, 95,98,00)	88,98,99, 00,01	PSACD 88,90,00,10	x
WF demand	FW consumption									x+PSACD	x
	Ch consumption									x+PSACD	x
	Gas consumption									x+PSACD	
	cons. Urban									x+PSACD	
	cons. Rural									x+PSACD	
	Cons. change rates									SEMIS (96) 87-92-96	
Socio-economic	Primary school		x		x						
	Health center		x		x						
	Drinking water		x		x					?x	
	Market		x		x						
	Roads	x 8 categ.	x		x						
	Literacy								x		
	French proficiency								x		
WF supply	Land use/ land cover	DAT/USAID 1982 31 classes (CSE 2000 pending)							PSACD 43 classes ref USAID 1982		
	Stocking										
	Productivity										
	Protected areas	5 categories									
	Land use changes									FAO FRA 2000; USGS/CSE 2003	

Annex 2: Demand parameters

Files : **conscenario_pop**; **conscenario_92_96ch**

Field name	unit	Total	Description
OBJECTID			
Shape			
AREA	ha	19,702,274	Total area (ha)
ADMI1			Region
ADMI2			Department
ADMI3			Arrondissement
ADMI4			Communautè Rurale (CR)
NOMCR			Name of CR
CSE_URB76		1,946,618	Urban population 1976 (CSE sencom data)
CSE_URB88		3,139,833	= 1988
CSE_URB90		3,334,007	= 1990
CSE_URB92		3,549,701	= 1992
CSE_URB95		3,920,964	= 1995
CSE_URB96		4,059,441	= 1996
CSE_URB98		4,362,038	= 1998
CSE_URB2000		4,703,536	= 2000
CSE_URB2003		5,303,534	= 2003
CSE_URB2005		5,774,130	= 2005
CSE_URB2010		7,277,688	= 2010
PSACD_rur_rate	comp.rate		Regional growth rates of rural population (PSACD 1998).
Rur90		4,355,468	Rural population 1990
Rur92		4,517,202	= 1992
Rur95		4,773,361	= 1995
Rur96		4,862,540	= 1996
Rur98		5,046,867	= 1998
Rur2000		5,239,478	= 2000
CSErur2001		5,339,018	= 2001
Rur2003		5,544,833	= 2003
Rur2005		5,760,000	= 2005
Rur2010		6,341,959	= 2010
Rur_FW_SATUR		See regional saturation values	Regional saturation values of rural fuelwood users
Rur_CH_SATUR			Regional saturation values of rural charcoal users
Rur_GPL_SATUR			Regional saturation values of rural GPL users
Urb_FW_SATUR			Regional saturation values of urban fuelwood users
Urb_CH_SATUR			Regional saturation values of urban charcoal users
Urb_GPL_SATUR			Regional saturation values of urban GPL users
RurFW_usercons		See regional percapita consumption values	Regional values of percapita consumption of rural fuelwood users
RurCH_usercons			Regional values of percapita consumption of rural charcoal users
RurGPL_usercons			Regional values of percapita consumption of rural GPL users
UrbFW_usercons			Regional values of percapita consumption of urban fuelwood users
UrbCH_usercons			Regional values of percapita consumption of urban charcoal users
UrbGPL_usercons			Regional values of percapita consumption of urban GPL users
Rur96_FWcons	tons	1,042,176	Rural fuelwood consumption 1996 (Semis/DE survey)
Rur96_CHcons	tons	155,000	Rural charcoal consumption 1996 (Semis/DE survey)
Rur96_GPLcons	tons	6,305	Rural GPL consumption 1996 (Semis/DE survey)
Urb96_FWcons	tons	135,842	Urban fuelwood consumption 1996 (Semis/DE survey)
Urb96_CHcons	tons	176,464	Urban Charcoal consumption 1996 (Semis/DE survey)
Urb96_GPLcons	tons	63,885	Urban GPL consumption 1996 (Semis/DE survey)

Scenario A:

Field name	unit	Total	Description
Rur90_FWcons_A	tons	945,337	Rural fuelwood consumption 1990 - Scenario A
Rur90_CHcons_A	tons	139,202	Rural charcoal consumption 1990 - Scenario A
Rur90_GPLcons_A	tons	5,499	Rural GPL consumption 1990 - Scenario A
Urb90_FWcons_A	tons	108,349	Urban fuelwood consumption 1990 - Scenario A
Urb90_CHcons_A	tons	145,683	Urban Charcoal consumption 1990 - Scenario A
Urb90_GPLcons_A	tons	54,543	Urban GPL consumption 1990 - Scenario A
Rur95_FWcons_A	tons	1,025,211	Rural fuelwood consumption 1995 - Scenario A
Rur95_CHcons_A	tons	152,228	Rural charcoal consumption 1995 - Scenario A
Rur95_GPLcons_A	tons	6,162	Rural GPL consumption 1995 - Scenario A
Urb95_FWcons_A	tons	130,602	Urban fuelwood consumption 1995 - Scenario A
Urb95_CHcons_A	tons	170,646	Urban Charcoal consumption 1995 - Scenario A
Urb95_GPLcons_A	tons	62,088	Urban GPL consumption 1995 - Scenario A
Rur00_FWcons_A	tons	1,113,605	Rural fuelwood consumption 2000 - Scenario A
Rur00_CHcons_A	tons	166,690	Rural charcoal consumption 2000 - Scenario A
Rur00_GPLcons_A	tons	6,915	Rural GPL consumption 2000 - Scenario A
Urb00_FWcons_A	tons	160,132	Urban fuelwood consumption 2000 - Scenario A
Urb00_CHcons_A	tons	203,216	Urban Charcoal consumption 2000 - Scenario A
Urb00_GPLcons_A	tons	72,340	Urban GPL consumption 2000 - Scenario A
Rur05_FWcons_A	tons	1,211,557	Rural fuelwood consumption 2005 - Scenario A
Rur05_CHcons_A	tons	182,763	Rural charcoal consumption 2005 - Scenario A
Rur05_GPLcons_A	tons	7,771	Rural GPL consumption 2005 - Scenario A
Urb05_FWcons_A	tons	200,141	Urban fuelwood consumption 2005 - Scenario A
Urb05_CHcons_A	tons	246,757	Urban Charcoal consumption 2005 - Scenario A
Urb05_GPLcons_A	tons	86,776	Urban GPL consumption 2005 - Scenario A
Rur10_FWcons_A	tons	1,320,237	Rural fuelwood consumption 2010 - Scenario A
Rur10_CHcons_A	tons	200,644	Rural charcoal consumption 2010 - Scenario A
Rur10_GPLcons_A	tons	8,746	Rural GPL consumption 2010 - Scenario A
Urb10_FWcons_A	tons	255,550	Urban fuelwood consumption 2010 - Scenario A
Urb10_CHcons_A	tons	306,505	Urban Charcoal consumption 2010 - Scenario A
Urb10_GPLcons_A	tons	107,817	Urban GPL consumption 2010 - Scenario A
FW90_A_m3	m^3	1,453,360	Fuelwood consumption 1990 Scenario A
FW95_A_m3	m^3	1,594,225	Fuelwood consumption 1995 Scenario A
FW00_A_m3	m^3	1,756,879	Fuelwood consumption 2000 Scenario A
FW05_A_m3	m^3	1,947,170	Fuelwood consumption 2005 Scenario A
FW10_A_m3	m^3	2,173,500	Fuelwood consumption 2010 Scenario A
CH90_A_w_m3	m^3	2,357,665	Wood for charcoal consumption 1990 Scenario A
CH95_A_w_m3	m^3	2,672,063	Wood for charcoal consumption 1995 Scenario A
CH00_A_w_m3	m^3	3,061,294	Wood for charcoal consumption 2000 Scenario A
CH05_A_w_m3	m^3	3,554,651	Wood for charcoal consumption 2005 Scenario A
CH10_A_w_m3	m^3	4,197,096	Wood for charcoal consumption 2010 Scenario A
TotWood90_A_m3	m^3	3,811,025	Total wood consumption (fuelwood + wood for charcoal) 1990 - Scenario A
TotWood95_A_m3	m^3	4,266,287	Total wood consumption (fuelwood + wood for charcoal) 1995 - Scenario A
TotWood96_m3	m^3	4,368,008	Total wood consumption (fuelwood + wood for charcoal) 1996
TotWood00_A_m3	m^3	4,818,173	Total wood consumption (fuelwood + wood for charcoal) 2000 - Scenario A
TotWood05_A_m3	m^3	5,501,821	Total wood consumption (fuelwood + wood for charcoal) 2005 - Scenario A
TotWood10_A_m3	m^3	6,370,596	Total wood consumption (fuelwood + wood for charcoal) 2010 - Scenario A

Scenario B:

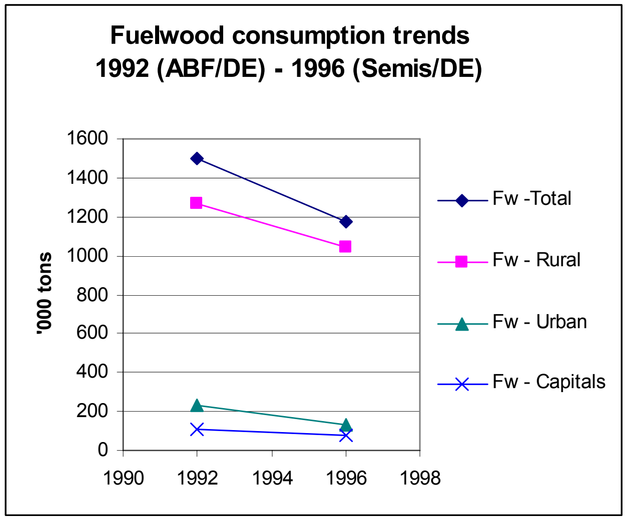
Field name	unit	Total	Description
RurFW_Change	comp.rate	0.935	Annual change rate of **rural fuelwood** consumption (ABF 92 and Semis 1996)
RurCH_Change	comp.rate	1.123	Annual change rate of **rural charcoal** consumption (ABF 92 and Semis 1996)
RurGPL_Change	comp.rate	1.102	Annual change rate of **rural GPL** consumption (ABF 92 and Semis 1996)
UrbFW_Change	comp.rate	0.845	Annual change rate of **urban fuelwood** consumption (ABF 92 and Semis 1996)
UrbCH_Change	comp.rate	0.865	Annual change rate of **urban charcoal** consumption (ABF 92 and Semis 1996)
UrbGPL_Change	comp.rate	1.113	Annual change rate of **urban GPL** consumption (ABF 92 and Semis 1996)
Rur90_FWcons_B	tons	1,410,793	Rural fuelwood consumption 1990 - Scenario B
Rur90_CHcons_B	tons	69,227	Rural charcoal consumption 1990 - Scenario B
Rur90_GPLcons_B	tons	3,064	Rural GPL consumption 1990 - Scenario B
Urb90_FWcons_B	tons	297,813	Urban fuelwood consumption 1990 - Scenario B
Urb90_CHcons_B	tons	346,652	Urban Charcoal consumption 1990 - Scenario B
Urb90_GPLcons_B	tons	28,629	Urban GPL consumption 1990 - Scenario B
Rur95_FWcons_B	tons	1,095,954	Rural fuelwood consumption 1995 - Scenario B
Rur95_CHcons_B	tons	135,498	Rural charcoal consumption 1995 - Scenario B
Rur95_GPLcons_B	tons	5,590	Rural GPL consumption 1995 - Scenario B
Urb95_FWcons_B	tons	154,574	Urban fuelwood consumption 1995 - Scenario B
Urb95_CHcons_B	tons	197,172	Urban Charcoal consumption 1995 - Scenario B
Urb95_GPLcons_B	tons	55,764	Urban GPL consumption 1995 - Scenario B
Rur00_FWcons_B	tons	852,734	Rural fuelwood consumption 2000 - Scenario B
Rur00_CHcons_B	tons	265,557	Rural charcoal consumption 2000 - Scenario B
Rur00_GPLcons_B	tons	10,213	Rural GPL consumption 2000 - Scenario B
Urb00_FWcons_B	tons	81,608	Urban fuelwood consumption 2000 - Scenario B
Urb00_CHcons_B	tons	114,017	Urban Charcoal consumption 2000 - Scenario B
Urb00_GPLcons_B	tons	111,173	Urban GPL consumption 2000 - Scenario B
Rur05_FWcons_B	tons	664,552	Rural fuelwood consumption 2005 - Scenario B
Rur05_CHcons_B	tons	521,128	Rural charcoal consumption 2005 - Scenario B
Rur05_GPLcons_B	tons	18,688	Rural GPL consumption 2005 - Scenario B
Urb05_FWcons_B	tons	43,920	Urban fuelwood consumption 2005 - Scenario B
Urb05_CHcons_B	tons	67,227	Urban Charcoal consumption 2005 - Scenario B
Urb05_GPLcons_B	tons	228,191	Urban GPL consumption 2005 - Scenario B
Rur10_FWcons_B	tons	518,729	Rural fuelwood consumption 2010 - Scenario B
Rur10_CHcons_B	tons	1,023,983	Rural charcoal consumption 2010 - Scenario B
Rur10_GPLcons_B	tons	34,242	Rural GPL consumption 2010 - Scenario B
Urb10_FWcons_B	tons	24,147	Urban fuelwood consumption 2010 - Scenario B
Urb10_CHcons_B	tons	40,548	Urban Charcoal consumption 2010 - Scenario B
Urb10_GPLcons_B	tons	485,135	Urban GPL consumption 2010 - Scenario B
FW90_B_m3	m^3	2,356,697	Fuelwood consumption 1990 Scenario B
FW95_B_m3	m^3	1,724,867	Fuelwood consumption 1995 Scenario B
FW00_B_m3	m^3	1,288,748	Fuelwood consumption 2000 Scenario B
FW05_B_m3	m^3	977,202	Fuelwood consumption 2005 Scenario B
FW10_B_m3	m^3	748,794	Fuelwood consumption 2010 Scenario B
CH90_B_w_m3	m^3	3,441,752	Wood for charcoal consumption 1990 Scenario B
CH95_B_w_m3	m^3	2,753,127	Wood for charcoal consumption 1995 Scenario B
CH00_B_w_m3	m^3	3,141,297	Wood for charcoal consumption 2000 Scenario B
CH05_B_w_m3	m^3	4,869,147	Wood for charcoal consumption 2005 Scenario B
CH10_B_w_m3	m^3	8,809,915	Wood for charcoal consumption 2010 Scenario B
TotWood90_B_m3	m^3	5,798,449	Total wood consumption (fuelwood + wood for charcoal) 1990 - Scenario B
TotWood95_B_m3	m^3	4,477,994	Total wood consumption (fuelwood + wood for charcoal) 1995 - Scenario B
TotWood00_B_m3	m^3	4,430,045	Total wood consumption (fuelwood + wood for charcoal) 2000 - Scenario B
TotWood05_B_m3	m^3	5,846,349	Total wood consumption (fuelwood + wood for charcoal) 2005 - Scenario B
TotWood10_B_m3	m^3	9,558,709	Total wood consumption (fuelwood + wood for charcoal) 2010 - Scenario B

Annex 3: Household fuels consumption trends 1992 - 1996

(ABF/DE 1992 – SEMIS/DE 1996)

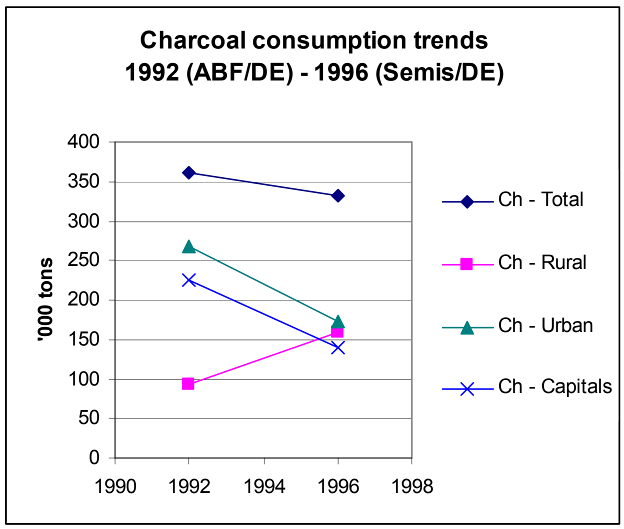
Survey ABF/DE 1992 (Association Bois de Feu [French NGO]/Direction de l'Energie),

Survey SEMIS/DE 1996 = Etude sur les énergie domestiques au Sénégal. Service de l'Energie en Milieu Sahélien/ Ministère de l'énergie, des mines et de l'industrie, Direction de l'Energie)



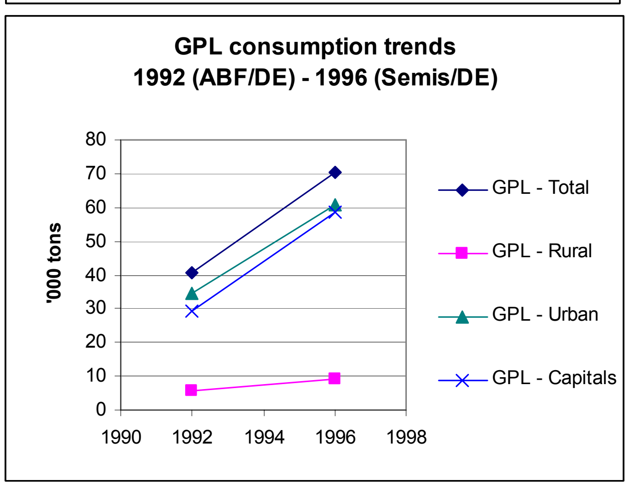
Household Fuelwood consumption

'000 t	1992	1996
Fw -Total	1496	1178
Fw - Rural	1267	1045
Fw - Urban	229	133
Fw - Capitals	108	81



Household Charcoal consumption

'000 t	1992	1996
Ch - Total	361	331
Ch - Rural	93	159
Ch - Urban	268	172
Ch - Capitals	225	140



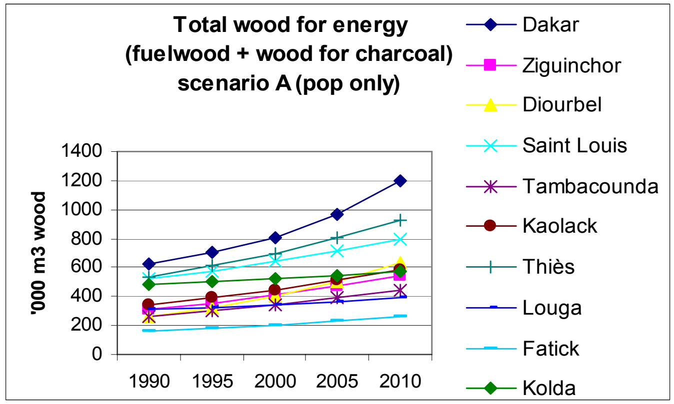
Household GPL consumption

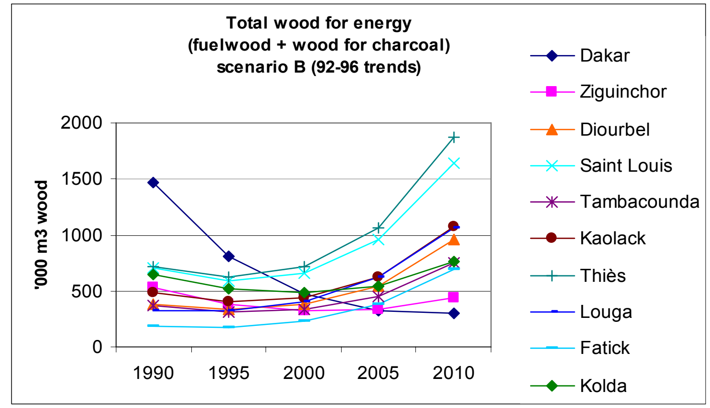
'000 t	1992	1996
GPL - Total	41	70
GPL - Rural	6	9
GPL - Urban	35	61
GPL - Capitals	29	59

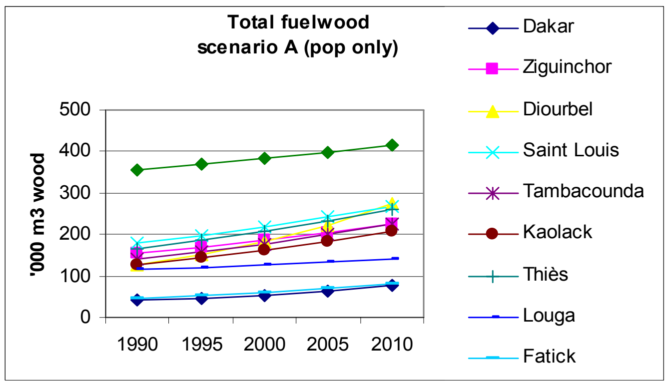
Annex 4: Regional consumption scenarios

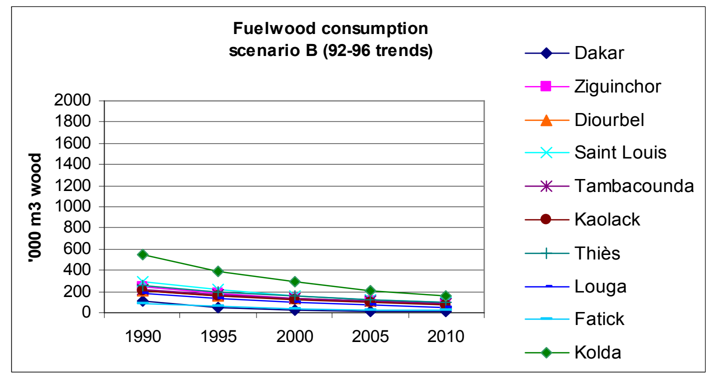
Left column: scenario A, based on 1996 consumption pattern and projected on population growth rates.

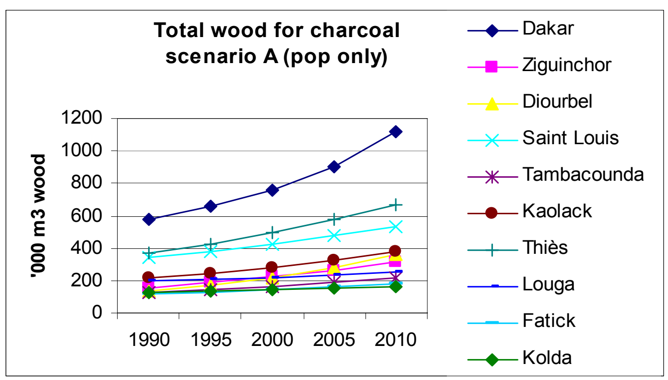
Right column: scenario B, based on 1996 consumption pattern and projected on rural and urban population growth rates and on the ABF/DE 1992 - SEMIS 1996 trends.

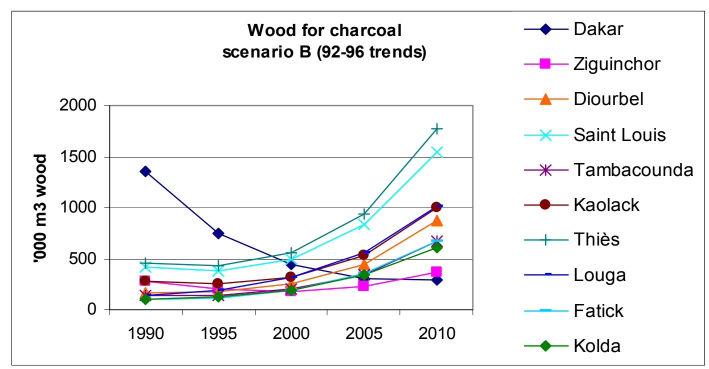












Annex 5: Senegal land cover classes, stocking, productivity and change rates

FORMcode	Formations (USAID	1982	Growth m^3/ ha/ year	Stock m^3 / ha	"EROS" 1965-2000 change rates	"FRA" 1985-2000 change rates
12	**FORETS GALERIES**	124,661	**2.5**	**140.0**	0.984997	0.993023
19	**FORETS DENSES HUMIDES**	1,034	**2.5**	**140.0**	0.984997	0.993023
17	**FORETS CLAIRES ET FORETS DENSES SEMI-SECHES**	16,109	**3.0**	**125.0**	0.984997	0.993023
18	**PALMERAIES ET FORETS SECONDAIRES**	29,377	**2.5**	**75.0**	0.984997	0.993023
11	**SAVANES TRES BOISEESET FORETS CLAIRES**	1,471,477	**1.6**	**57.5**	0.998121	0.993023
13	**FORETS CLAIRES SECHES**	315,549	**1.5**	**53.1**	0.984997	0.993023
16	**FORETS CLAIRES HUMIDES**	71,391	**2.0**	**50.0**	0.984997	0.993023
14	**FORETS CLAIRES SECHES, SAVANES BOISEES ET ST**	140,386	**1.5**	**50.0**	0.984997	0.993023
15	**FORETS SECONDAIRES**	30,035	**1.5**	**50.0**	0.984997	0.993023
20	**FOURRES**	9,065	**2.0**	**40.0**	0.991149	0.993023
21	**MANGROVES**	181,990	**2.0**	**40.0**	0.991149	0.993023
8	**SAVANES BOISEES**	3,155,978	**1.0**	**25.7**	0.998121	0.993023
9	**SAVANES BOISEES A ARBUSTIVES**	110,737	**1.0**	**25.0**	0.998121	0.993023
10	**SAVANES BOISEES PARSEMEES DE STEPPES**	1,532,828	**1.0**	**25.0**	0.998121	0.993023
7	**SAVANES ARBOREES ET BOISEES**	1,093,042	**1.0**	**11.9**	0.998121	1
6	**SAVANES ARBOREES**	12,762	**0.5**	**5.6**	0.998121	1
5	**SAVANES ARBUSTIVES ET ARBOREES**	1,401,702	**0.4**	**4.4**	0.998121	1
3	**STEPPES ARBOREES**	221,107	**0.3**	**4.0**	0.998121	1
2	**STEPPES ARBUSTIVES ET ARBOREES**	1,050,750	**0.2**	**2.9**	0.998121	1
4	**SAVANES ARBUSTIVES**	1,904,088	**0.2**	**2.3**	0.998121	1
1	**STEPPES ARBUSTIVES**	1,878,048	**0.1**	**0.5**	0.998121	1
22	**TANNES**	203,014	**0.1**	**0.3**	1.006999	1.007
23	**VASIERES DENUDEES**	92,761	**0.1**	**0.3**	1.006999	1.007
24	**PRAIRIES MARECAGEUSES**	45,346	**0.1**	**0.3**	1.006999	1
25	**STEPPES HERBACEES**	2,534	**0.1**	**0.3**	1.006999	1.007
26, 27, 29	**AUTRES ZONES**	34,319	**0.1**	**0.3**	1.006999	1.007
31	**ZONES DE CULTURE**	4,138,042	**0.1**	**0.3**	1.007	1.009
30	**EAUX LIBRES**	101,502	**0.0**	**0.0**	1	1
	Total	**19,369,633**				

Stock and growth values are weighted on the areas of the subtypes reported by PSACD (valley, plateaux, pénéplaines) .

Sources: Land cover classes: USAID/DAT 1985; Socking and growth: PSACD 1998 and J. PIOT, A. Ly, I. Guèye, 1991; Change rates EROS /CSE 2003 and FAO FRA 2000 (see Annex 3 for details)

Annex 6: Main references on Senegal's land cover changes

FAO FRA2000

	Land use 1985		forest 1990	forest 2000	Forest cover change 1990-2000	
	%	000 ha	000 ha	000 ha	000 ha	%
Tot forest	34.5%	6781	6655	6205	-45	-0.7
closed forest	1.6%	324				
open forest	32.8%	6457				
shrubs, trees woodlands	41.1%	8086				
fallow	20.1%	3957				
other lands	2.2%	428				
inland water	2.1%	419				
Total	100.0%	19671				

Source: FAO FRA 2000

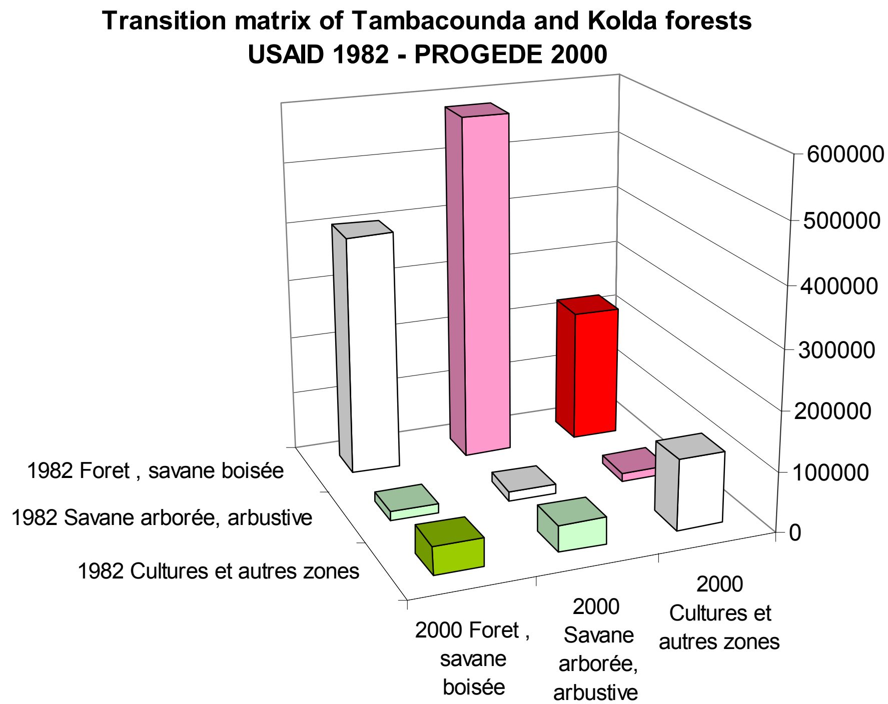
USGS/CSE 2003

	Land use 1965	Land use 2000	1965-2000
	%	%	Change rate
Forests	3.9	2.3	0.9850
Savannas	70.2	65.7	0.9981
Wetlands	0.6	0.7	1.0044
Steppes	1.8	2.3	1.0070
Mangroves	1.5	1.1	0.9911
Agriculture	18.3	23	1.0065
Water bodies	1.7	1.8	1.0016
Sandy areas	0.1	0.1	1.0000
Bare soils	1.7	2.7	1.0133
Settlements	0.2	0.3	1.0116
	100.0	100.0	

Source: "Ecoregions and Land-Cover Trends in Senegal" Tappan,G. G., M. Sall, E. C. Wood, M. Cushing , (USGS/EROS Data Center; Centre de Suivi Ecologique, Dakar) 2003.

Transition matrix resulting from the intersection of DAT/USAID vegetation map (reference date 1982) and the Land cover map of the areas of Tambacounda and Kolda studied by PROGEDE (reference date 2000).

Areas in ha	2000 Foret , savane boisée	2000 Savane arborée, arbustive	2000 Cultures et autres zones	Total 1982
1982 Foret , savane boisée	405752	583607	225656	1215015
1982 Savane arborée, arbustive	15670	16050	15348	47067
1982 Cultures et autres zones	46173	44423	119828	210423
Total 2000	467594	644079	360832	1472505



Transition types

Transition types	
Cultures to forests	Possible afforestation
Cultures to savannas and savannas to forests	Possible amelioration (increase of biomass)
Forest o savannas and savannas to cultures	Possible degradation (loss of biomass)
Forests to cultures	Possible deforestation

The two maps present differences that are not due only to land cover changes, since they were produced following different methods and using different classification systems. For the table above the original classes were collapsed to achieve a somewhat comparable level. Still, the transitions should be taken only as rough indication of land cover changes. The changes with lower gradient (indicated above as possible amelioration and degradation processes) are particularly unreliable, although the large dominance of negative trends may indicate a serious degradation process. The changes with higher gradient (afforestation and deforestation) are probably more reliable. The resulting annual net deforestation rate is -0.9%, which is slightly higher than the national rates estimated by the two sources mentioned in the previous page.

Annex 7: Estimated exploitable volumes

Accessibility	Protected area types	**Exploitable fraction for energy use**		Total growth (1982) m³	**Exploitable volume for energy use** m³	Exploitable fraction and volumes for other uses	m³	Inaccessible and non exploitable fraction and volume	m³
Accessible areas < 3 km from roads and villages	non protected	**0.75**	20% is left out as untouched or for other uses	6,187,183	**4,640,387**	0.05	309,359	0.2	1,237,437
	zp1_NP national parks	**0.00**	No exploitation foreseen	351,439	**0**	0.00	0	1.0	351,439
	zp2_RSP reserves sylvo-pastorales	**0.50**	Restrictions assumed as for Forets Classées	212,642	**106,321**	0.30	63,793	0.2	42,528
	zp3_FC Forets Classées	**0.50**	The rest is left out for other industrial uses or as uneconomical	829,132	**414,566**	0.30	248,739	0.2	165,826
	zp4_notitle unknown category	**0.50**	Unknown restrictions . Assumed as Forets Classées	15,507	**7,753**	0.30	4,652	0.2	3,101
	zp5_noname unknown name and category	**0.50**	Unknown restrictions . Assumed as Forets Classées	18,528	**9,264**	0.30	5,558	0.2	3,706
Less accessible areas > 3 km from roads and villages	non protected	**0.55**	50% is left out as inaccessible or for other uses	3,093,556	**1,701,456**	0.05	154,678	0.4	1,237,422
	zp1_NP national parks	**0.00**	No exploitation foreseen	405,458	**0**	0.00	0	1.0	405,458
	zp2_RSP reserves sylvo-pastorales	**0.40**	Restrictions assumed as for Forets Classées	92,555	**37,022**	0.20	18,511	0.4	37,022
	zp3_FC Forets Classées	**0.40**	The rest is left out for other industrial uses or as inaccessible/uneconomical	622,174	**248,870**	0.20	124,435	0.4	248,870
	zp4_notitle unknown category	**0.40**	Unknown restrictions . Assumed as Forets Classées	1,265	**506**	0.20	253	0.4	506
	zp5_noname unknown name and category	**0.40**	Unknown restrictions . Assumed as Forets Classées	14,112	**5,645**	0.20	2,822	0.4	5,645
total				11,843,552	**7,171,790**		932,801		3,738,961
					61%		8%		32%

Annex 8: Supply parameters

Files : **conscenario_pop**; **conscenario_92_96ch**

Field name	unit	Total	Description
ADMI4			Communauté Rurale
Stock_82	000 m3	294,757	Stocking in 1982, mean date of reference map (DAT/USAID)
Growth_82	000 m3	11,844	Annual productivity in 1982, mean date of reference map (DAT/USAID)
St_85_EROS	000 m3	291,008	Stocking in 1985 according to “EROS” change rate scenario
St_90_EROS	000 m3	285,009	= 1990 =
St_95_EROS	000 m3	279,303	= 1995 =
St_00_EROS	000 m3	273,870	= 2000 =
St_05_EROS	000 m3	268,692	= 2005 =
St_10_EROS	000 m3	263,753	= 2010 =
Gr_85_EROS	000 m3	11,724	Productivity in 1985 according to “EROS” change rate scenario
Gr_90_EROS	000 m3	11,532	= 1990 =
Gr_95_EROS	000 m3	11,348	= 1995 =
Gr_00_EROS	000 m3	11,173	= 2000 =
Gr_05_EROS	000 m3	11,005	= 2005 =
Gr_10_EROS	000 m3	10,844	= 2010 =
St_85_FRA	000 m3	289,274	Stocking in 1985 according to “FRA” change rate scenario
St_90_FRA	000 m3	280,391	= 1990 =
St_95_FRA	000 m3	271,817	= 1995 =
St_00_FRA	000 m3	263,543	= 2000 =
St_05_FRA	000 m3	255,557	= 2005 =
St_10_FRA	000 m3	247,852	= 2010 =
Gr_85_FRA	000 m3	11,662	Productivity in 1985 according to “FRA” change rate scenario
Gr_90_FRA	000 m3	11,370	= 1990 =
Gr_95_FRA	000 m3	11,088	= 1995 =
Gr_00_FRA	000 m3	10,816	= 2000 =
Gr_05_FRA	000 m3	10,555	= 2005 =
Gr_10_FRA	000 m3	10,304	= 2010 =
Acces_Growth_82	000 m3	7,172	Accessible annual productivity at map-reference date (1982)
Acces_Gr_85_EROS	000 m3	7,100	Accessible productivity in 1985 according to “EROS” change rate scenario
Acces_Gr_90_EROS	000 m3	6,984	= 1990 =
Acces_Gr_95_EROS	000 m3	6,873	= 1995 =
Acces_Gr_00_EROS	000 m3	6,768	= 2000 =
Acces_Gr_05_EROS	000 m3	6,667	= 2005 =
Acces_Gr_10_EROS	000 m3	6,570	= 2010 =
Acces_Gr_85_FRA	000 m3	7,065	Accessible productivity in 1985 according to “FRA” change rate scenario
Acces_Gr_90_FRA	000 m3	6,891	= 1990 =
Acces_Gr_95_FRA	000 m3	6,725	= 1995 =
Acces_Gr_00_FRA	000 m3	6,565	= 2000 =
Acces_Gr_05_FRA	000 m3	6,411	= 2005 =
Acces_Gr_10_FRA	000 m3	6,262	= 2010 =
Acces_Stock_82	000 m3	176,319	Accessible stocking at map-reference date (1982)
Acces_St_85_EROS	000 m3	174,099	Accessible stocking in 1985 according to “EROS” change rate scenario
Acces_St_90_EROS	000 m3	170,545	= 1990 =
Acces_St_95_EROS	000 m3	167,164	= 1995 =
Acces_St_00_EROS	000 m3	163,945	= 2000 =
Acces_St_05_EROS	000 m3	160,876	= 2005 =
Acces_St_10_EROS	000 m3	157,949	= 2010 =
Acces_St_85_FRA	000 m3	173,065	Accessible stocking in 1985 according to “FRA” change rate scenario
Acces_St_90_FRA	000 m3	167,792	= 1990 =
Acces_St_95_FRA	000 m3	162,705	= 1995 =
Acces_St_00_FRA	000 m3	157,795	= 2000 =
Acces_St_05_FRA	000 m3	153,057	= 2005 =
Acces_St_10_FRA	000 m3	148,486	= 2010 =

Annex 9: Supply/Demand balance parameters

Files : Bal_accFRA Bal_accEROS

Field name	unit	Total	Description
ID			
ADMI4			
Bal00_accEROS_fwA	m^3	5,014,162	Accessible "EROS" productivity – total Fuelwood - 2000 – Scenario A
Bal05_accEROS_fwA	m^3	4,722,789	= = - 2005 =
Bal10_accEROS_fwA	m^3	4,399,770	= = - 2010 =
Bal00_accEROS_fwB	m^3	5,482,385	Accessible "EROS" productivity – total Fuelwood - 2000 – Scenario B
Bal05_accEROS_fwB	m^3	5,692,948	= = - 2005 =
Bal10_accEROS_fwB	m^3	5,824,755	= = - 2010 =
Bal90_accEROS_WFA	m^3	3,175,461	Accessible "EROS" productivity – total Woodfuels - 1990 – Scenario A
Bal95_accEROS_WFA	m^3	2,609,407	= = - 1995 =
Bal00_accEROS_WFA	m^3	1,951,680	= = - 2000 =
Bal05_accEROS_WFA	m^3	1,166,848	= = - 2005 =
Bal10_accEROS_WFA	m^3	201,272	= = - 2010 =
Bal90_accEROS_WFB	m^3	1,188,379	Accessible "EROS" productivity – total Woodfuels - 1990 – Scenario B
Bal95_accEROS_WFB	m^3	2,397,796	= = - 1995 =
Bal00_accEROS_WFB	m^3	2,339,196	= = - 2000 =
Bal05_accEROS_WFB	m^3	820,123	= = - 2005 =
Bal10_accEROS_WFB	m^3	-2,992,311	= = - 2010 =
Bal00_accFRA_fwA	m^3	4,811,228	Accessible "FRA" productivity – total Fuelwood - 2000 – Scenario A
Bal05_accFRA_fwA	m^3	4,466,740	= = - 2005 =
Bal10_accFRA_fwA	m^3	4,092,203	= = - 2010 =
Bal00_accFRA_fwB	m^3	5,279,451	Accessible "FRA" productivity – total Fuelwood - 2000 – Scenario B
Bal05_accFRA_fwB	m^3	5,436,899	= = - 2005 =
Bal10_accFRA_fwB	m^3	5,517,188	= = - 2010 =
Bal90_accFRA_WFA	m^3	3,083,183	Accessible "FRA" productivity – total Woodfuels - 1990 – Scenario A
Bal95_accFRA_WFA	m^3	2,461,098	= = - 1995 =
Bal00_accFRA_WFA	m^3	1,748,747	= = - 2000 =
Bal05_accFRA_WFA	m^3	910,799	= = - 2005 =
Bal10_accFRA_WFA	m^3	-106,295	= = - 2010 =
Bal90_accFRA_WFB	m^3	1,096,101	Accessible "FRA" productivity – total Woodfuels - 1990 – Scenario B
Bal95_accFRA_WFB	m^3	2,249,487	= = - 1995 =
Bal00_accFRA_WFB	m^3	2,136,263	= = - 2000 =
Bal05_accFRA_WFB	m^3	564,074	= = - 2005 =
Bal10_accFRA_WFB	m^3	-3,299,878	= = - 2010 =