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USE OF CROP-RESIDUES IN THE AGRICULTURAL SYSTEMS OF SENEGAL.

A Country Report

Invitational paper

by

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ABSTRACT

This study involved a survey of animal production systems and an inventory of crop by-products available in the farming sector in Senegal. Cattle are the dominant class of livestock, followed by sheep and goats, although both contribute to the cash economy. The major factor affecting iivestock production is feed shortage during the dry season. Overgrazing leading to degeneration of vegetal cover, and the recent drought conditions, bave made the situation worse. Several crop residues and agro-industrial by-products were identified as alternative feeds and potential supplements. The constraints associated with their efficient use are emphasized. More collaborative research between NARS within the eco-region and strengthened partnerships with IARCs are needed to make better use of these feed resources for increased animal production of benefit to the population, without adverse effects on the environment.

INTRODUCTION

Senegal is situated in West Africa, on the atlantic coast, in the intertropical zone between latitude 12°30'and 16°30'N and longitude 11°30' and 17°30' W. It has a land area of 196, 722 km2 and a population estimateu at 8 million inhabitants. Two ecological zones can be distinguished according to rainfall patterns, the Sahelian zone in the North and the Sudano-Guinean zone in the South of the country . Rainfall is unimodal, occuring betwen July and September, and ranges in average from 200 mm in the North to 1500 mm in the South. This short rainy season is followed by a long dry season from October to June during which rain never occurs.

The basis of Senegal economy is agriculture. Agriculture employs more than 70% of the population, accounts for 13 % of the Gross Domestic Product (GDP), and makes an important contribution to export eamings (Etude sectorielle de l'élevage, 1982). The livestock sector, although characterised by low productivity, contributes to about 6.5% of

the GDP and 32% of the Agricultural GDP (Ministère des Ressources Animales, 1988) and traditionally plays an important socio-cultural role in the country GDP (Ministère des Ressources Animales, 1988; Ly, 1989). The major constraints that affect ruminant livestock include health, genetics, management, nutrition and socioeconomics (Cissé, 1991). The country is faced with food shortages, and is struggling to sustain food security.

Per capita annual meat consumption per capita has consistently decreased over years, from 21.5 kg in 1960, 13 kg in 1974, 12.5 kg in 1985, and 9.5 kg in 1987 (Ministère des Ressources Animales, 1988). Local milk production in 1987 was estimated to 1 100 000 hl per year, with 1 300 000 hl of milk being imported to make good the deficit (M'Baye, 1988). Ruminant livestock supply 77% of locally produced meat and 29% of the milk and dairy products consumed (Richard et al., 1989). With the present human population growth of 2.7% per year, increases in meat and milk production are a political-economic priority . The objective is to produce 183 000 tons of milk and 121 600 tons of meat in order to reach at least the targeted per capita meat consumption of 15.7 kg by the year 2000 (Ministère des Ressources Animales, 1988).

I. IMPORTANCE AND ROLE OF LIVESTOCK IN AGRICULTURAL SYSTEMS

1. Importance of livestosk

During the last two decades, the trend was a slight increase in the cattle population because severe drought affected the large ruminants more than the small ruminants in the 1970s (Table 1). The rate of small ruminant increase was higher than that of any other species, due to their better resistance to drought and their selective feeding behaviour (specially goats) on pastures, when compared to cattle which are grazers (Guérin et al., 1988, Cissé et al., 1993).

The cattle population increased by only 6% from 1970- 1977 to 1990- 1994, while the sheep and goat numbers increased by over 44.7% during the same period (cattle 2,462,000 in 1970-1977 to 2,612,000 in 1990-1994; sheep and goats 2,647,000 in 1970 to 3,831,000 in 1990) (Direction de l'Elevage, 1970- 1994). This trend is also a result of the actual increased pressure on land for cropping .

2. Role of livestock in major agricultural systems

Animal production mvolves both non-ruminants and ruminants, and a variety of systems more or less integrated with crops (Table 2). Three major agricultural systems closely related to agro-ecological zones have been identified:

.the pastoral system in the sylvo-pastoral zone in the North and East,
.the agro-pastoral system in the Centre and in the South,
.the peri-urban system.

-The pastoral system

The livestock management consists of a transhumant pastoralism practiced by the Peuh1 ethnic group whose major means of livelihood is almost exclusively cattle production on extensive grazing land area (Diop, 1989). Household income and food supply depend mainly on livestock.

Cattle are reared on natural pastures with sheep and/or goats and have to trek great distances in search of fodder and water (Diop, 1987; Diop 1991). Nutrition is a major limiting factor in pastoral systems. Availability and adequacy of feeds fluctuate with seasons. Pasture productivity varies from 100 to 2,000 kg of dry matter per hectare from year to year, and from 500 to 1,800 kg dry matter according to the types of pastures (Boudet, 1984; Richard et al., 1989). Nutritional value of natural forage has been extensively investigated in Casamance, in the South of the country (Boudet, 1970) and in

(Boudet, 1984; Richard et al., 1989). Nutritional value of natural forage has been extensively investigated in Casamance, in the South of the country (Boudet, 1970) and in the sylvo-pastoral area (Guérin, 1987) and, recently, in Sangalcam, in the periurban zone of Dakar (Cissé et al., 1993) (Figure 1). When rainfall is adequate, there is abundant forage which however matures quickly and enters dry-dormancy at the end of the dry season. The result is feed inadequacy in terrns of both quantity and quality (Richard et al., 1989). Crop production is marginal in this livestock production system.

-The agro-pastoral system

The farming system is predominantly based on the rainfed agriculture producing groundnut, cereals, and livestock, using few external inputs and based on mainly family labour and animal draught power (Fall, 1986; Lhoste, 1987; Fayé, 1993). Livestock are kept in semi-sedentary mixed farming systems, where people do not shift homesteads during the year. This system is practiced by local groups such as Ouolof and Serere in the Center and Diola, Mande and Fulani in the South of the country, and their main activity is agriculture.

The major crops grown are groundnut, cereals such as maize, millet, sorghum and rice, and cotton. Other crops include beans and palm-trees. Rice is produced both in the north in the valley of the Senegal river, and in the Casamance region in the South (Figure 1). Sugar cane is produced only along the Senegal river. Most people operating within the system cultivate by hand and rarely with tractors. Cultivation of fodder plants remains very limited. Oxen are widely used for cropping and transport (Fall, 1986; Faye, 1993) and overall integration of livestock is rare. The integration of crop and livestock sectors involves not only the use of draught animals but also the use of crop residues and manure deposit into cropping areas. Another form of integration is the income transfert from one sector to the other.

Livestock have crucial importance to the farming system which benefited from a certain level of trop-livestock integration (Faye and Landais, 1985). The main

sources of smallholders income are crop sales (small proportion of total grain and a large proportion of groundnut produced), wage employment, ans sales of livestosck and livestock products. Livestock are purchased and sold according to the farmer's cash flow needs. Some ruminant and poultry (Buldgen et al., 1992b) are also kept for home consumption and to meet other socio-cultural needs. In this system, a migratory pastoral component is maintained to a certain extent, particularly with cattle which do migrate over long distances during the dry season, whereas sheep and goats are kept near the homestead with access to household and kitchen wastes when available.

Animal nutrition during part of the dry season depends mainly on cereals straws, more or less associated with browsing, and with supplementation provided by certain fat-mers or extension agencies. The main supplements used are groundnut haulms, artisanal or industrial groundnut cake, and cotton seed to a lesser extent.

-The peri-urban system

There is a specific type of livestock production system in the periurban zone which is the main area for agribusiness in the form of extensive (Diao, 1991; Cissé et al., 1996c) or intensive (Diop et al., 1992) dairy, and poultry entreprises (Arbelot, 1994). The intensive dairy cattle production uses imported breeds in order to meet the increased demand for milk. Exotic breeds such as Pakistanese cows were introduced in 1963, Montbeliard in 1976, Jersey in 1988 (Diop et al., 1992), and Holstein cows more recently , in 1994. Today the major unit of milk production is SOCA (Société Agro-alimentaire) using jersey cows in the periurban zone of Dakar (Sow, 1991). Animals are fed with green (beans) or ensiled forages (maize, sorghum) from irrigated plots. Lactating cows are supplemented with locally purchased agro-industrial by-products such as groundnut cake, cereal brans, and cotton seed.

Vegetable (onions, sweet potatoes, tomatoes, green vegetables, carrot) and fruit production (mangoes, oranges, water melons, papayas, etc...) (Seck, 1991) generate important quantities of by-products in the periurban zone mainly in Dakar, and in Saint-Louis (Figure 1).

3. Impact of mechanization on the use of livestock in agricultural systems

In the Senegalese peanut basin, population growth and the extensive use of animal traction have favored the excessive expansion of cultivated land to the detiment of the pastoral land area. Traditional practices of maintaining soil fertility have been disturbed by pastoral land restrictions (Faye, 1993). Pressure on land and the encroachement of cropping lands on pastures has caused a reduction in the cattle population in the groundnut bassin and a shift to the use of cows for draught purposes. The use of horses and donkeys for cropping and transport has increased.

Agricultural production in the country has been better organised over the past two deeades and more and more development plans give priority to food production for domestic use, with resultant increase in the agriculture-based industries.

With the decline and degradation of grazing lands through overgrazing and the expansion of arable cropping, agricultural by-products take on greater significance. For example, cotton production increased from 1,000 tons in 1987 (Plan d'Action pour l'Elevage, 1988) to 50,000 tons in 1991-1992 (Direction de l'Agriculture, 1992). Cocsequently, the use of cotton seed, a major protein source, greatly increasëd for beef and sheep fattening in the Center and in the South of the country. In 1986, 887,820 tons of maize, millet, snrghum and rice grain were harvested. The estimated straw output is 4,800,000 tons (Fall et al., 1989). An increase in available quantities of straws could be expected with the development of irrigated cropping in the Senegal river valley and mechanisation .

II. USE OF CROP RESIDUES AS LIVESTOCK FEED RESSOURCES

1. Farmer's current practices on utilizing crop residues as a source of livestock feed in major agricultural systems.

Natural pastures and crop residues are the primary feedstuffs at the disposa1 of animals (Adegbola and Smith, 1982). The crop residues include almost all post-harvest remains of crops grown within the farming systems and their utilization differ according to the residue and the system. Rice straw is burned, not fully used in the Senegal river valley, and grazed ***in situ***, in the South. Other cereal straws (millet, maize and sorghum stovers) are cutted ans stocked in the Diourbel zone for later use, or freely grazed ***in situ*** on crop fields after harvest, in other regions. Legume haulms (beans, groundnuts etc.. .) are fed near the homesteads where they are stored after threshing. Maize is harvested in September while pastures are still green. At this period, since animals are not yet allowed access to crop lands, it can be assumed that important quantities are lost (Fall, 1986). With the population growth, use of crop residues will take on greater importance with intensification of cropping and of livestok production.

The feeding of crop residues is common in certain farming systems. Some farmers practice supplementation using tree-crops (green or dry leaves or pods) with agro-forestry species including *Leucaena* ***leucocephala,*** *Guiera* ***senegalensis; Acacia*** *sp.*, **etc..** (Fall, 1993). Browses species occupy an important place in small ruminant feeding, particularly during the dry season (Guérin et al., 1988; Cissé et al., 1993). This is because most browse species are drought resistant and provide proteins, vitamins and minerals which are lacking in herbage species. Other supplementary feeds are obtained from agro-industrial by-products such as residues of oil extracted from oil bearing seeds (groundnut, palmkemel, cotton seed), by-products of grain processing (millet, rice, wheat, sorghum, maize), peelings of crops (yams, sweet potatoes, etc.. .) and industrial by-products (brewers'dried grains, fruit cannery by-products, molasses etc.. .). The types and quantities available tend to be location and season specific.

2. Availability of the crop residues

Quantitative estimates of crop residues are not usually reported in national statitics. Groundnut and millet are the major crops in Senegal. Groundnut haulms are therefore the most abundant crop residue (Table 3). Millet straws are second in importance. There are widely used as animals feed. The other crop residues and agro-industrial by-products (Table 2) include cereal and legume straws, wheatbran, dried brewers'grains (spent grains from the breweries), oilseed cakes, cottonseed cake and palmkernel) and cereal bran. Without the availability of crop residues, ruminants could hardly survive the long dry season.

In years where statistical data on agro-industrial by-products have been reported, large quantities are found. High quantities of them (groundnut cake, cotton seed, palmkernel cake, molassis) are however exported (Etude sectorielle de l'élevage au Sénégal, 1982).

3. Current practices used in processing crop residues

Cereal straws and groundnut haulms are scattered on the farms after harvesting the grains. Sorghum stalks retain a better quality if harvested early, dried and stored off the ground on man made storage facilities. Bundles of rice straw, weighing 10- 13 kg, and groundnut haulms are marketed as animal The main customers are transport businesses with draft animals, and the peri-urban milk and meat producers.

Most of the groundnut grown in the country is locally processed into oil. The remaining cake is a valuable source of energy and protein. The industrial cake is exported. The domestic cake and cereal bran are the major by-products useful as animal feed which are produced at the village level. There is a certain import of wheat processed locally into flour. However, the quantity of wheat bran appears to be limited.

are produced at the village level. There is a certain import of wheat processed locally into flour. However, the quantity of wheat bran appears to be limited.

Cereal crop residues are important feed resources in the mixed farming systems. However these residues are high in lignocellulose compounds and are characterized by low protein content, and low digestibility and voluntary intake (Sall, 1984; Fall et al., 1989). When fed atone to ruminants, as practiced by several farmers, they can not support maintenance requirements.

A great deal of research on forages has been done in various research centres and feeding recommandations were formulated for farmers. Improvement in the nutritional value of straws with physical treatments and supplementation with other by-products (Table 5), and good animal performances were reported with on station-research. Chemical treatment of straws (Blancou and Calvet, 1977) is restricted by costs, technical ability and safety. However, urea seems promising (Fall et al., 1989; Cissé et al., 1995b, 1996a; Gongnet et al., 1996), because it is cheap and easy to obtain at the village level. The evaluation of its profitability at the farm level is going on in the Senegal valley river with rice straw and in the peanut basin, in the Center, with natural pasture straw.

4. Current practices used to supplement crop residues

In the agropastoral system, farmers commonly use crop residues supplemented with artisanal groundnut cake, and cotton seed, or they can mix various crop residues for animal feeding.

In the agricultural areas, farmers generally waste feed resources and consequently animals are over or underfed. There is an often ineffective collection of the groundnut haulms which is by far the most important and the best quality feed for animals. If they still contain many leaves, groundnut haulms can support daily gains of 0.5 kg liveweight for thin cattle after a dearth period. Millet, maize and sorghum straws represent

30 to 50% of the cattle diet during the dry season and a smaller part of the small ruminant's diet, in agro-pastoral zones (Richard et al., 1989).

Many years of research on the nutritive value of every type of crop residue in several combinations showed technical advantages of using these resources (Table 5) as animal feed. The technologies generated (diets formulated with many agro-industrial by-products) without economic analysis are beyond the reach of farmers. Research on both pasture and agricultural by-products has had a very limited impact on livestock productivity in the small-scale farming sy stems .

5. Major constraints on utilization of crops residues as livestock feed

The major constraints associated with the use of by-products are their bulkiness, transportation, storage and processing.

After harvesting the grains, cereal straws have to be bulked and transported to the villages and stored. The first problem encountered is transport both on farm and on a regional basis where by-products may be located in a different area to livestock.

The second problem is the amount of labour required to collect and store the crop residues. People are busy harvesting crops and do not take time to collect and store the crop residues (Fall, 1986). Another constraint is the actual manner of storage, whether on platforms, in the field, fenced, etc...Moreover, there are no machines in the villages to process these straws for incorporation in diets for ruminants. In the harvesting process, development of simple machinery such as choppers or chaffcutters would be beneficial in reducing by-product particle size.

Inadequate and inefficient use of the available technology is also a major limitation to increased animal production.

6. Nutritive value of crop residues

An important study was carried out to determine the nutritive value of (1) native herbages of natural pastures in the Sahelo-sudanian zone, (2) fodder grasses cultivated under irrigation and (3) some crop residues and agro-industrial by-products (groundnut haulms and cake and cereals straws) encountered in Senegal. The determination of their chemical composition (Table 3), digestibility and feeding trials results allowed the establishment of Feed Tables (Richard et al., 1989). However, other studies are needed to specify the feeding value of each by-product with high potential.

The feeding values of millet, maize and sorghum straws are very low. Their dry matter digestibility ranged from 42.8 to 49% (Sall, 1984, Fall et al., 1989, Gongnet et al., 1996) and their organic matter digestibility depends on the leaf/stem ratio (0.2-0.35), and ranges from 40-45 % for the entire straws and from 50-55 % for the leaves. Rice straw has a higher organic matter digestibility (56%) (Richard et al., 1989) than the other straws.

The energy content of groundnut haulms varies between 0.50 to 0.72 UFL/kg DM and their digestible protein content between 40 to 74/kg DM, depending on the leaf/stem ratio (0.2 to 1.5 according to harvesting practices) (Richard et al., 1989). Rice bran has a chemical and a nutritive value negatively affected by high levels of silica (12.2% .DM) and ADL (8.2% DM), as a consequence of a high proportion of hulls.

Most of the forages have insufficient mineral content (P, Ca, Na, Cu and Zn) to meet the requirements of livestock (Cissé, 1985; Guérin et al., 1989; Cissé et al., 1996b). Some trace elements content such as Cu and Zn are, in most of the forages, under the limit of deficiency.

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Studies on the toxicity of crop residues (gossipol content of cotton seed, and other toxic constituents like alkaloïds, glucosides, polyphenols, hydrocyanic acid, oxalic acid, etc.. .) are very scarce. However, detoxification of groundnut cake against aflatoxine is required for EU exports.

7. Opportunities for collaborative research on strategies for using crop residues as animal feeds.

Feed is the principal constraint among the non genetic factors affecting animal production, particularly during the dry season. Fodder is of poor nutritional value for most of the year due to the rainfall pattern, and crop residues and other feed resources are greatly underused. This situation will be worsened if livestock productivity and population increase. However, there is an immense potential for improving animal nutrition and therefore production by using crop by-products. The use of farm-produced by-products (stovers, straws, bean and groundnut haulms and household offals) and agro-industrial by-products as animal feed is an efficient and ecologically sound use of feed resources.

Attention must be given to research on forage production and agricultural by-products which are an important feed resource in animal production systems. Increased intensification and efficiency in the use of feeds is most important and emphasis should be given to feeds that do not compete with human food.

In the sylvo-pastoral area where tbe production system is pastoral, increased fodder production will be possible witb the rehabilitation project to improve water availability in fossiled valleys, as are corrections of minera1 deficiencies. Adapted forage can provide nutrients for ruminants. More productive and high yielding forage crops need research. The agronomic characteristics of tbese forages need to be determined in order to achieve maximum benefits from them. Fertiliser requirements, frequency of cutting, cutting

height, grass/legume mixtures and other factors affect the yield and nutitional value of forages.

There is need to increase investments for research on mixed farming systems within each agro-ecological zone. Research into integrating crop and animal production is essential, especially for the areas where crop production is the farmers'primary preoccupation.

Collaborative research can focus on:

-the inventory the type and availability of crop residues
-the study the feeding value and toxicity of crop residues
-the improvement of the technology for conservation of crop residues
-the improvement of the nutritive value of fibrous foods
-the maximisation of the use of agricultural by-products in beef and sheep finishing operations
-the breeding of cereals of higher nutritive value
-the investigation of the use of fodder trees adapted to the various locations

8. Role of agribusiness in development of novel feed products by utilizing the locally available feed resources

There is a need for technology or institutional support for the private sector but the policy area needs clarification. Govemment has a role to play in ensuring the

availability of support services and infrastructure that producers need in order to make best uses of by-products.

Government policy should promote the optimal use of the local feed resources in the animal industry and improve the capacity of the private sector capacity to respond to the market environment. With the devaluation of the CFA franc by 50% in February 1994, exports of agro-industrial by-products increased.

9. The **institutions involved in research and development of livestock feed based on crop residues: their speciality and linkages with advanced institutions in developed countries and with IARCs.**

In the recent past, some international institutions such as FAO, CIRAD, ILRI through AFRNET and IDRC have funded research projects on the use of by-products, in Senegal .

Factors limiting the utilisation of technical packages at the small-holder level include poor coordination between research institutions and development organisations. Researchers do not get enough feedback information to enable them to plan their research activities based on the needs of farmers. So, projects are usually proposed on their own perceived problems.

In order to facilitate the immediate diffusion of technologies generated by the scientists into the farming systems, a well-organised extension system is required. It is also important to improve linkages between researchers and extension workers to share experiences (through joint research proposals), and the extension services have to be strengthened through training extension staff.

It is also important to note that, in Senegal as in several developing countries, the level of research funding and the infrastructure in terms of laboratories and facilities and trained manpower are limited. Partnerships between NARs, IARCs and other regional institutions on common research needs on the use of crop residues has to be strengthened.

This can be done through a better exchange of information, training, participation in workshops and otherscientific meetings.

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Table 1: Trends in livestock species in the last two decades (Direction de l'élevage, rapports annuels 1970-1994)

Livestock species	Population (,000) 1970/77	1983/89	8 change over the period (1970-1989)
Cattle	2462	2397	-3
Sheep & goat	2647	4471	+69
Pigs	256	204	-26
Horse	209	289	+38
Camel	7	9	+43
Pouitry		10500	

Table 2 **Major agricultural systems in different agro-ecological zones in** Senegal

Agro-ecological Zone	**Major agricultural sys tems**	**Main Livestock Products**	**Predominant** Feeding **sys tem**
Sahelian (200-500mm)	Goats/cattle/sheep Rice, sugar-cane vegetables:tomatoes, onions, beans, cassava fruit: water melons	meat milk	Pasture grazing By-products
Sahelo-soudanian (500-700mm)	Cattle/sheep/goats groundnut, millet sorghum, maize Vegetables: tomatoes, potatoes, beans carrot, cassava and fruits: mangoes, oranges	meat milk	Pasture grazing Groundnut haulms Cereal straws Commercial concen-trate
Soudano-sahelian (700-900mm)	Cattle/sheep/goats Groundnut, millet sorghum, maize, cotton	meat milk	Pasture grazing Groundnut haulms Cereal straws Cotton seed
Soudanian (900-1200mm)	Cattle/sheep/goats Cotton, Groundnut millet,sorghum, maize,	Meat	Pasture grazing Groundnut haulms Cotton seed Cereal straws
Soudano-guinean (1200-1800mm)	Cattle/goat/sheep Rice, groundnut millet, sorghum, palm-trees, vegetables: beans, cassava, fruits: banana mangoes, oranges	Meat	Pasture grazing crop residues Browsing tree-foliages

Table 3: Agricultural **and agro-industrial by-product feed** resources **available in Senegal**

Feeds	Quantities (tons)	References*
Rice straw	170,000	3
Maize straw	102,633	3
Millet straw	592,505	3
Sorgho straw	78,094	3
Groundnut haulms	1,500,000	2
Bean haulms		
Wheat bran	20,000	2
Rice bran	10,000	4
Millet bran	-	
Wet brewers'grain	1,000	4
Groundnut husk		
Cotton seed	50, 000	3
Tomato industrial dehydrated residues		
Groundnut cake	100 à 300,000	3
Cotton seed cake	5,000	2
Cotton seed husk	8,800	2
Palmkernel oil cake	4,000	1
Molassis	30,000	2
Bagasse	300,000	2

*1.Etude sectorielle de l'élevage au Sénégal, 1982
2.Plan d'Action pour l'élevage, 1988
3.Direction de l'Agriculture, 1992
4.Direction de l'Elevage, 1992.

Table 4: Nutritive value of some agro-industrial by-products available in Senegal

Crop residues	Constituents*							
	DM %	CP %	CF %	DMD	Ca	P	Cu	Zn
	(on a dry matter basis)			%	g/kg DM		(mg/kg DM)	
Rice straw (*Oryza sativa*)	92.3	23	34.5	42.8	1.7		5.8	44
Millet straw (Pennisetum *americanum*)	85	56	41.4	39.2	1.6	2.3	4.0	14.7
Sorghum straw (*Sorghum bicolor*)	77.4	39	40.3	47.2	.41	.43	17.9	76.5
Maize straw (*Zea* mays)	86	38	38.6	49.3	2.0	1.5		
Bean haulms (*Phaseolus sp.*)	89.3	13	29		1.35	0.29		
Groundnut haulms (*Arachis hypogea*)	87.2	10.7	34.2	54.8	9.2	1.2	5.6	19
Natural pasture straw								
Groundnut husks	98.6	61	34.8	18.4	0.6	0.4		
Millet bran	83.9	13.9	20		1.1	5.1		
Rice bran	93.3	51	76		0.8	3.4		
Cottonseed	86.6	20.6	33.0					
Cotto'nseed husk	93.2	70	48.9		1.3	1.4		
Cottcnseed cake	92.3	10.3	30.6		1.5	12.7		
Molassis	10	56	0		7.3	0.7		
Maize bran	90.4	9.8	8.9		.04	.14		
Groundnut cake	97.8	48.5	50		1.2	4.6		
Wet brewers'grain	22.9	5.0	4.6					
Tomato industrial dehydrated residues	96	9.4	43.4					

*dry matter (DM), crude protein (CP), crude fiber (CF), dry matter digestibility (DMD), calcium (Ca), phosphore (P), cuivre (Cu) et zinc (Zn).

Source: Blancou et Calvet, 1977; Fall et al., 1987; Cissé et al., 1995a; Cissé et al., 1996b; Gongnet et al., 1995; Richard, unpublished data; Cissé, unpublished data.

Table 5: Inventory of main agricultural by-products research undertaken i Senegal during the period 1969-1995.

Main agricultural by-product	References
Rice straw	Calvet et Valenza, 1973 Calvet et al., 1974ab Sall, 1984 Fall et al., 1989 Lemal et al., 1989 Richard et al., 1989 Steyaert et al., 1989a Gongnet et al., 1996
Millet straw	Richard et al., 1989 Cissé et al., 1995a
Sorgho straw	Richard et al., 1989 Steyaert et al., 1989 Cissé et al., 1995a
Natural pasture straw	Buldgen et al., 1992 Buldgen et al., 1993 Cissé et al., 1995a
Groundnut husk	Calvet et al., 1969 Boudergues et Calvet, 1970 Calvet et Denis, 1974 Calvet, 1977 Sall, 1987 Steyaert et al., 1989a Cissé et al., 1994
Groundnut haulms	Richard et al., 1989
Cotton seed	Calvet et al., 1973 Fabre et al., 1973 Faye, 1993

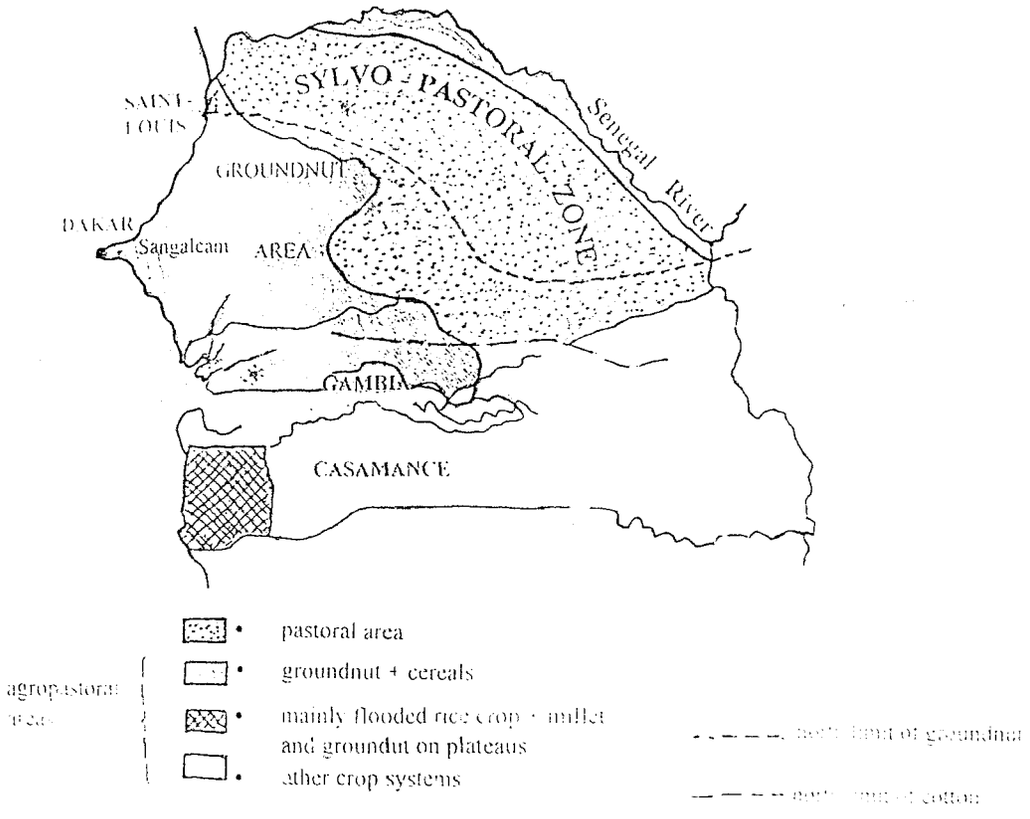

Figure 1 - Distribution of main crops and breeding systems in Senegal (Richard et al., 1989)