# Land cover and avian biodiversity in rice fields and mangroves of West Africa

Daan Bos
Ion Grigoras &
Abdoulaye Ndiaye

WETLANDS INTERNATIONAL

**Mission:**

To sustain and restore wetlands, their resources and biodiversity for future generations through research, information exchange and conservation activities, worldwide.

The west coast of Africa, from southern Senegal to Sierra Leone, is characterised by extensive mangrove vegetation, interspersed with rice-fields and tidal flats. Many millions of people live in this area and depend on its resources - rice, fish, wood etc. The region is of great biological importance, particularly since it harbours extensive wetlands that function as staging sites for Afro-tropical and migrating Palaearctic birds. Over the past decades, rainfall has been erratic and the severe droughts in the 1970s and 1980s impacted on the existing mangrove stands and rice fields.

A change in land cover over time could also have occurred due to developments in management and the socio-economical framework. Such change potentially affects people and biodiversity. In this report we aim to quantify the availability of different wetland habitats for birds and the changes therein, over the past 15 to 20 years. Furthermore we investigate the composition of the bird populations in the different wetland types and identify the threats to these systems.

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Disclaimer: The views expressed in this paper do not necessarily reflect the positions of the Dutch government.

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**Data availability**
Datafiles related to this study are available upon request from Wetlands International, Dakar.

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# Foreword

Mangrove ecosystems and the rice plantation zones are both of high importance for their intrinsic value, their crucial importance for biodiversity and their economic value.

In West Africa, the mangrove zone stretching along the coast from the south of Senegal (Casamance) through The Gambia, Guinea-Bissau and Guinea as far as Sierra Leone are strongly threatened by human exploitation. Behind the mangroves, rice plantations have been widely established in natural flood plains and these are also facing difficulties due to irrational exploitation.

It is consequently important to know better the ecology of this unique rice and mangrove zone and to understand their role in supporting local economies and biodiversity. This improved knowledge will enable governments and communities to plan better to avoid irrevocable losses. It is in this context that an integrated research programme was established in 2003 for this zone as a key component of the West Africa interventions of the International Biodiversity Policy of the Netherlands.

The mangroves and rice plantation ‘ecoregion’ was thus identified among three other ecoregions for its vital importance for millions of people and for biodiversity.

The results of the initial studies carried out between 2003 and 2006 highlight the importance of this zone as a habitat for biodiversity. They also identify and document the threats which this habitat faces and draw up recommendations for policies on settlement, exploitation and rational management.

Wetlands International is dedicated to the wise use and conservation of wetlands in Africa, and recognizes the vital contribution that the mangrove and rice zone makes to livelihoods and biodiversity in this region. We therefore appreciate this technical and scientific work as an important contribution to achieving long-term wise use of the natural resources and rice fields in this coastal zone of West Africa. I very much hope that this publication will help to promote this contribution and will ensure that socio-economic and ecological data are used when drawing up development plans in this important region.

Seydina Issa Sylla
Regional Director for Africa,
Wetlands International

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# Summary

Millions of people depend upon the natural resources in the coastal lowlands of West Africa. Here, stretching from southern Senegal to Sierra Leone, a zone exists where mangrove forests are prominent. To the seaward side, intertidal flats border the mangroves, while extensive rice-fields are found in the land beyond. This zone is referred to as the Rice and Mangrove Ecoregion in this study. The mangroves serve as habitat for many species of flora and fauna and have a range of ecological functions. Some of these functions are tangible and valuable for man. Behind the mangroves, large areas are used for cultivating rice. People in the region rely heavily upon the rice produced in these lowland rice fields. It is a type of rice cultivation that requires very delicate water management, specialist techniques and a significant amount of labour. This is related to the fact that soils in the ecoregion are sensitive to salinisation and acidification. Other important human activities are fisheries, salt-extraction, oyster harvesting and the collection of wood. A large part of the lowland rice fields is kept wet during the dry season in this part of Africa. Therefore, these rice fields are a habitat for many wetland related bird species, including migratory birds.

In this study we aim to identify existing threats to the ecosystem and give recommendations for sustainable management. Before doing so, we first quantify the value of the major wetland habitats for birds. Then, we estimate the changes over the past twenty years in the extent of the areas of the major habitats, and we link these developments to meteorological data for the same time period. In a parallel study to this (Duarte 2006) an attempt is made to illustrate the value of these wetlands for people.

The successful functioning of wetlands in the Rice and Mangrove Ecoregion is largely governed by the balance between fresh and salt water, in conjunction with the typical characteristics of the soil. On top of that there is the human influence. Man is dependent on this ecosystem but is affecting it as well, for example by interfering with the hydrology. In the second chapter of this study we therefore start to summarise the available knowledge on the socio-economic background, climate, soils, mangrove forest and rice fields. Following that, we present a series of land cover maps for the ecoregion, produced by remote sensing for the sake of this study, to quantify the extent of rice fields, mangroves and other natural vegetation in the lowlands. These recent land cover maps reflect the situation in early 2000. This evidence is compared to existing information derived from maps, literature and FAO databases, in order to evaluate the developments over time. The value of the different wetland habitats for birds is quantified using data on bird density, also gathered within the framework of this study. During the dry seasons of 2003–05 we established estimates of bird density for each habitat type, by counting birds in a sample of plots with known surface area and type.

Rainfall is one of the main climatic parameters affecting plant growth, and rainfall greatly varies within the ecoregion. Rainfall is abundant in the south, but limited in the north. Other climatic parameters vary in accordance with rainfall. Parts of the 1970's and the early 1980's have been characterised by below-average rainfall, a period known as the African drought. Particularly in the north of the ecoregion, the droughts have been very severe. Currently more favourable rainfall conditions appear to be prevailing.

The land cover maps that have been produced for this study are accompanied by measures of quality. This enabled us to illustrate that the accuracy of these current land cover maps is poor in the southern part of the ecoregion (Guinea and Sierra Leone), but quite acceptable for the countries in the northern part (Senegal, The Gambia, Guinea Bissau). The causes of this variation in quality are technical and are discussed in the report. The other available information on land cover in the past or at present is generally not at all associated with measures of quality, and the estimates for the area of rice and mangrove habitat vary greatly amongst them. For these reasons it has not been possible in this study to distinguish subtle trends on an ecoregional scale. We did, however, not find evidence of large-scale changes during the study period on the ecoregional scale, except for a decline in the area of mangrove in the south of Senegal during the African drought. On a local scale, changes may have been very important, but the methodology has not been applied for detecting these.

The methods of rice cultivation in the mangrove swamps generally have not changed over the past decades. Locally there are all kinds of developments - examples are the cutting of mangroves for new rice polders, the construction of larger-scale dams to prevent salt intrusion, the salinisation and acidification of existing fields, the recovery of degraded land, over-harvesting of wood, oysters or other resources and the adoption of newer, more sustainable harvesting strategies. Some of these developments are positive, and some are negative. No specific large-scale threats were observed. General threats are inappropriate water management, unsustainable oyster harvesting strategies and unlimited extraction of wood.

In this study, an extensive, detailed and quite consistent database has been collected on bird densities in the rice fields. Additional information on the composition of the bird community has been gathered in the lowland natural vegetation, the bare upper tidal areas and the mangroves. The different habitats harbour overlapping bird communities. Both rice and natural vegetations have value as bird habitat. With this data the relative importance of different vegetation communities and the role of different abiotic factors in relation to the birds' habitat requirements has been substantiated. The ecoregion is very important for many Afro-tropical species, as well as for migrating Palaearctic birds. The results provide a tool to better describe the nature of changes of any future modification of land cover. Throughout West Africa, there is a need and a desire to increase rice production. When planned and implemented carefully, this does not necessarily have a negative impact on biodiversity in birds.

Any interference with land use developments in the ecoregion will require a thorough insight into local conditions and adequate water management. The latter aspect can hardly receive sufficient emphasis, given the sensitivity of the soils to salinisation and acidification. Increasing the welfare of local populations, taking into account the natural constraints, requires the implementation of proper water management on an appropriate scale, but only after a careful evaluation of local conditions. It is also very necessary to provide local populations with the means to implement the use of alternative sources of energy. Among other things, it is furthermore recommended to evaluate more thoroughly the up and downstream effects of the anti-salt dams, in terms of biodiversity and economic benefits.


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# 1 Introduction

## 1.1 The Rice and Mangrove Ecoregion

The west coast of Africa, from the south of Senegal to Sierra Leone is characterised by extensive mangrove vegetation, interspersed with rice fields and tidal flats. Many millions of people live in this area and depend on its resources; rice, fish, wood etc. The region is also of great biological importance, particularly since it harbours extensive wetlands that function as staging sites for Afro-tropical and migrating Palaearctic birds. The area (see map 1.1) is referred to by a variety of names, depending on the point of view of the author. In Francophone literature, for example, it is called "les Rivières du Sud", while Anglophone traders have been using the name 'Northern Rivers' (Cormier-Salem 1999). Ecologically speaking, it is an entity, as we shall see in the next chapters. We will refer to this study area as the "Rice and Mangrove Ecoregion", since it is especially these components of the ecosystem in which we are interested here. The study area is defined as the area between 14º30' N and 7º30' N and confined to the lowlands (altitude < 30m); it includes the estuaries of the Sine-Saloum (Senegal) in the north and the Scarcies (Sierra Leone) in the south.

The mangrove ecosystem is tightly related to the balance between fresh and salt water (Bertrand 1999), and thus to rainfall. Over the past decades, rainfall has been erratic and the severe droughts in the 1970s and 1980s impacted on the existing mangrove stands and rice fields (Cormier-Salem 1999; Tappan *et al*. 2004). Other factors, too, influence the land-cover in this region, for example the availability of labour, and the management of water and soil. In the mangrove ecoregion, the soils are vulnerable, and management may have strongly adverse effects on the soil condition (Dent 1984). These factors act in concert and we hypothesize that there has been a measurable change in land cover over the past decades, due to the developments over time in each of them. Such changes potentially affect people and biodiversity, and that explains our interest.

**Landscape impressions.**

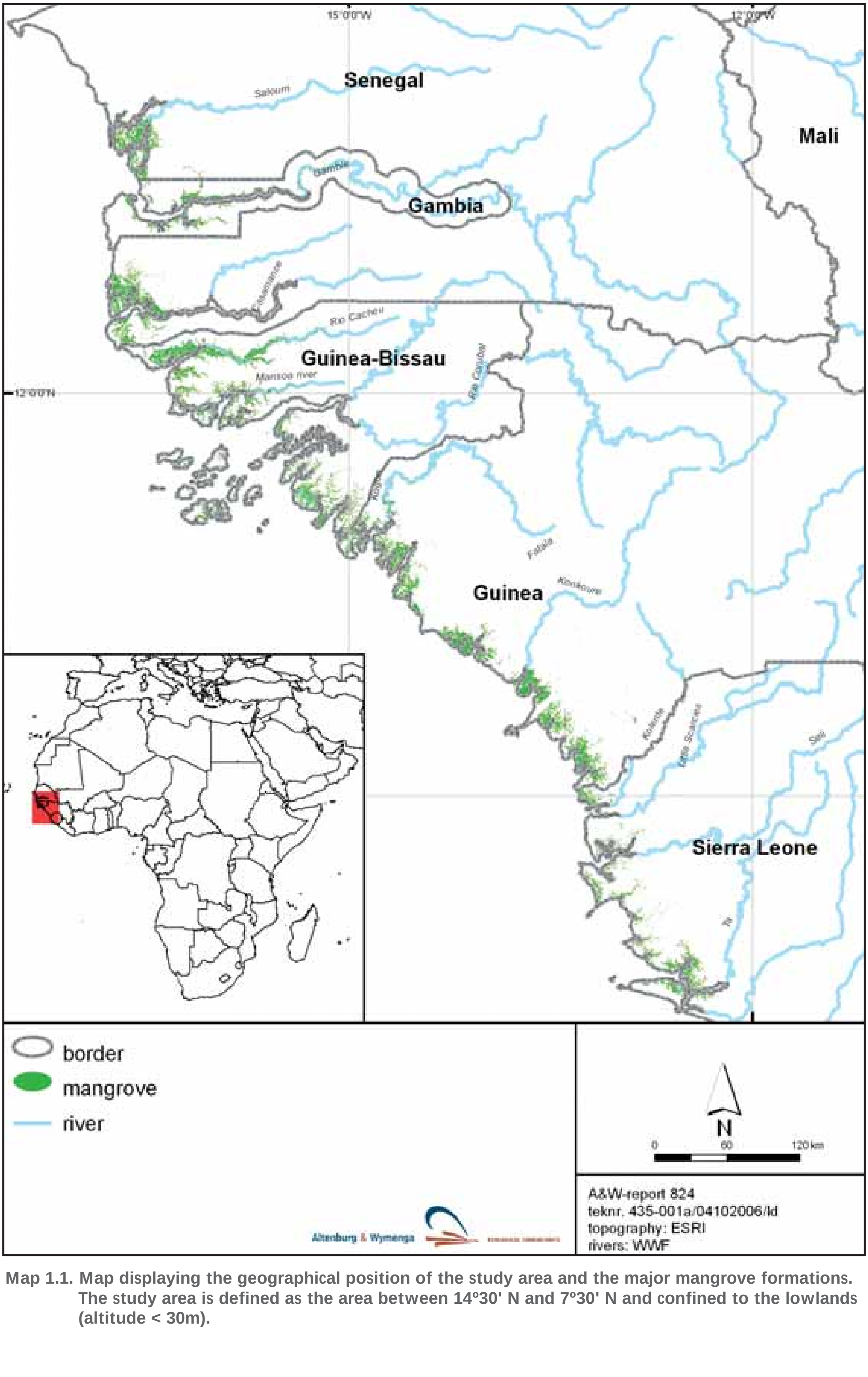
**a) Rice fields alternating with natural vegetation and open water. b) Vegetated tidal flats with *Sesuvium sp.* c) Bare uppertidal flat. d) Upland. e) Aquatic vegetation with *Nymphea sp.* f) Vegetated tidal flat.**

## 1.2 Scope of the study

In a parallel study to this one, within the framework of the same project, the value of the wetlands for people in the Rice and Mangrove Ecoregion is evaluated (Duarte 2006). There are many socio-economic aspects that need to be considered, that are relevant for the welfare of the local population, and that may contribute to a sustainable exploitation. The scope of this study is to quantify the availability of different wetland habitats for birds and the changes therein over the past 15-20 years. Also, we aim to investigate the composition of the bird populations in the different wetland types and the occurrence of threats to these systems.

### Bookmark

In the next chapters we will review the main abiotic and biotic phenomena affecting land cover in the Rice and Mangrove Ecoregion, with special attention to the human component. It is essential to present background information on these issues before we proceed with our own aims, methods and results. In chapter three we will describe our methodology in collecting information on land cover developments and bird density counts, our proximate for biodiversity. Chapter four presents the results, *i.e.* a classification of remotely sensed data for the entire ecoregion, a comparison with existing maps and data, and a summary of the bird density counts. In chapter five we will discuss our findings and identify threats to the ecosystem. We will finish with a limited set of recommendations, as far as our biological data will allow us. Wise use of the natural resources in the ecoregion depends on more than simply knowledge of the biological component alone. Recommendations for sustainable management need to take into account the economical and sociological issues that fall beyond the scope of this study.




**Map 1.1. Map displaying the geographical position of the study area and the major mangrove formations. The study area is defined as the area between 14º30' N and 7º30' N and confined to the lowlands (altitude < 30m).**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# 2

# Description of the Rice and Mangrove Ecoregion

The Rice and Mangrove Ecoregion is a lowland area, with many estuaries and a multitude of mangrove-fringed channels. Between the uplands and the sea, there are sand dunes, salt flats and mangrove-vegetated mud flats. Most of the area is under a tidal influence. People have used, and are still using the area for multiple purposes, but the main agricultural activity is the cultivation of rice. They have to operate in a very dynamic environment, within the constraints set by climate, hydrology, soil and given socio-economic conditions. Birds use different habitats according to their requirements, and also have to cope with the dynamics of these systems. Within a season, the conditions change with seasonal variations in rainfall and evaporation, while over the years the availability of the major habitats may not be constant. Here we will review the main abiotic and biotic phenomena affecting land cover in the Rice and Mangrove Ecoregion, with special attention to the human component.

**Impression of mangrove stands.**

**a) A dike through the mangrove forest leading to the village of Elia (Guinea Bissau). b) near Serekunda (The Gambia). c, d) *Rhizophora*. e) The remains of mangrove trees that have died during the African drought in the Bintang Bolon (Boudouk, Senegal 2005). f) uppertidal flat with remains of mangrove (Bintang Bolon, The Gambia 2005). g) Vervet monkeys in the Mangroves.**


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## 2.1 Historical and socio-economic background

The history of people and rice-cultivation in the region is a long one, and might date back more than two thousand years (Cormier-Salem 1999). Since then, people have used the mangrove environment to fish, to harvest salt, cockles and oysters and to grow rice. With the collection of wood for construction and fire these are still the major ways in which the natural resources are exploited. The various populations were specialised differently though, and each inhabited certain parts of the coastal zone. Over the centuries, there have been major shifts in the relative abundance and presence of varying ethnical groups.

The recent history is characterised by fast growing populations, especially in the urban areas. The total population has tripled between 1960 and 2005, whereas the urban population has increased sevenfold (see figure 2.1). It is noteworthy that all of the larger cities are found in the coastal zone (Cormier-Salem 1999). Above that, there has been a significant increase in the demand for rice, given population growth and dramatic changes in consumption patterns during the past two decades. Increasingly, rice is becoming the staple diet of urban households. The growth in consumption has been most substantial in these rapidly growing cities. In line with this, most of the countries concerned have adopted enhanced food security as a common policy goal (WARDA 2005), and thus they are aiming at increased rice production. There is also an increase in the demand for firewood or construction timber (Diombera 1999). Indeed, as an example, Diombera (1999) reports on declining stocks of timber in general. He finds strong decline in the area of mangrove, even accelerating after 1985, for Guinea-Bissau.

In spite of these growing populations, and increasing demand for rice, a shortage of labour is felt in the rice-cultivation areas (Cormier-Salem 1999). In the fifties and sixties Pélissier (1966) noted a rural exodus of young people, leading to abandonment of certain rice fields. With the climatic drought in the 1970s and 1980s this phenomenon has only increased (Cormier-Salem 1999). However, the rural areas remain home to many people that exploit the natural resources, as has been done for centuries. There is a continuous exchange of people and goods between the cities and the rural areas, and the welfare of all of these people is related to properly functioning ecosystems in the coastal zone.

**Human activity.**

**a) Women preparing oysters harvested that day (Banjul, The Gambia 2005). b) Return from rice fields c) Earthen dikes are created and maintained with manual force in the traditional system, using a specially adapted spade, suitable for this type of soil. The tool is up to four meters long, strong, and able to cut the clay. d, g and h) fishermen. e) Harvesting of reed in what used to be a tidal rice area (Dankunku, The Gambia 2005). f) Harvest of wood from mangrove stands (Soma, The Gambia 2005).**

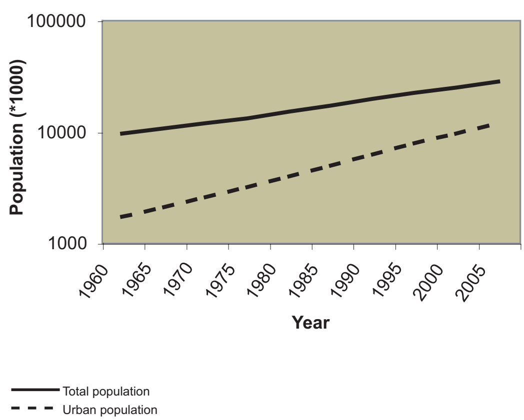



**Figure 2.1. Human population in Senegal, The Gambia, Guinea-Bissau, Guinea and Sierra Leone. (FAOSTAT data, 2006, last accessed May 2006). Note the logarithmic scale.**

## 2.2 Climate

The climate in the study area, and in West Africa in general, is determined by a humid air mass originating from the Atlantic Ocean, and by a dry air mass from the African continent. Where these two air masses meet, the Inter-Tropical Convergence Zone (ITCZ) is found. The seasonality of the West African climate results from the annual north-south migration of the ITCZ, due to the yearly positional changes of the Earth in relation to the sun. The position of the sun varies between the Tropic of Cancer (21 June) and the Tropic of Capricorn (21 December). The air, the soil and the ocean are heated most when the sun is directly overhead at noon. This causes a maximal rise of air. The upward-welling air flows to the north and the south at high altitude and returns to the earth thousands of kilometres away as very dry air. This circulation system, known as the Hadley cell, brings dry air to the Sahel from the Northeast in the dry season. When the sun, during the northern summer, is directly above the Sahara, humid air comes with the monsoon winds from the Atlantic Ocean in the southeast. This brings rain to the Sahel, bringing with it the wet season.

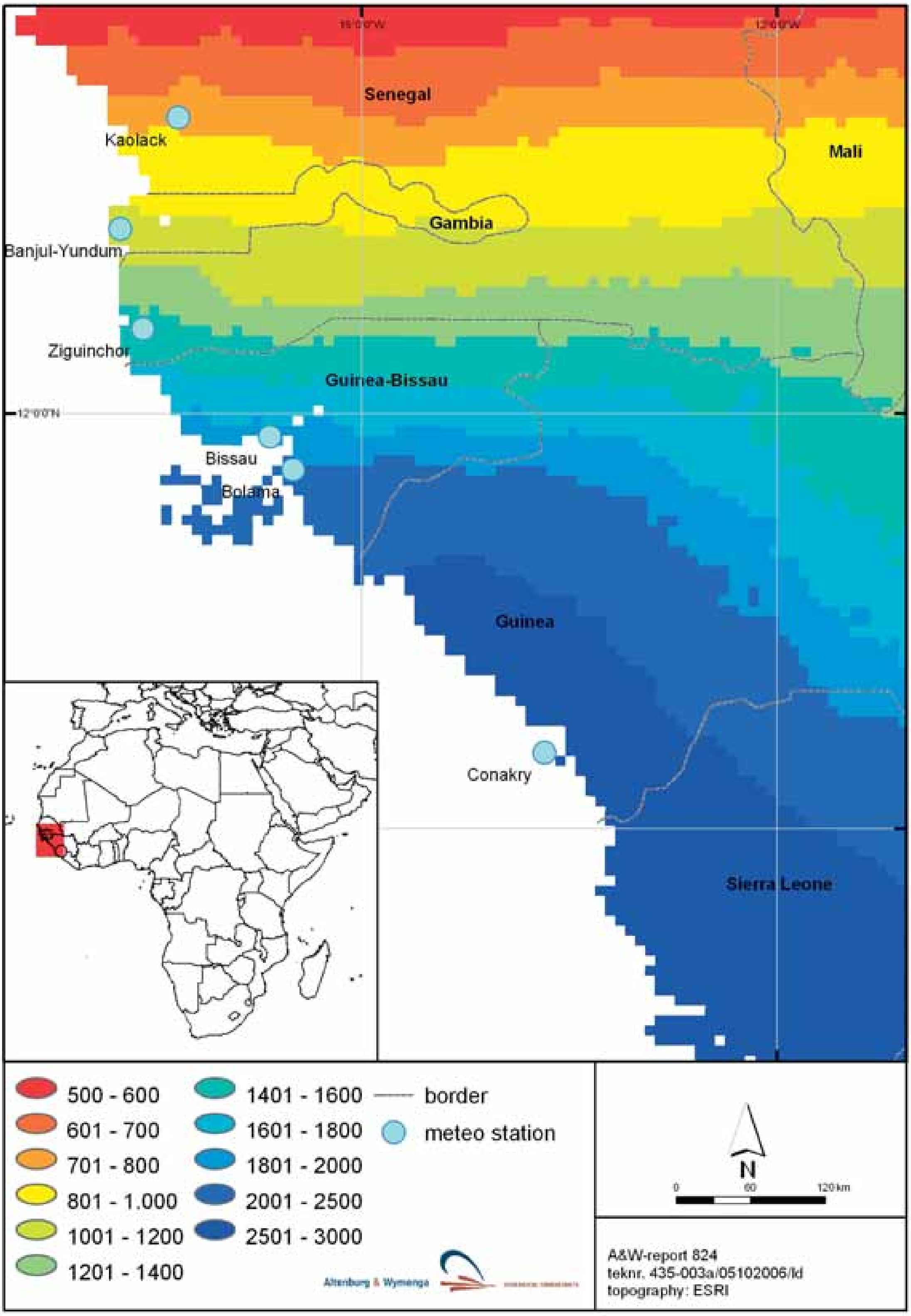
The Inter-Tropical Convergence Zone moves north and south of the equator and usually reaches its most northerly position in August. Its position defines the northern limits of possible rainfall in the Sahel. Rain-bearing clouds are generally situated 150-200 km south of the ITCZ. The ITCZ is the dominant rain making mechanism all over Africa, explaining why northern and southern Africa are dry and central Africa wet. It also explains why it rains in the Sahel during the northern summer and rains a half year later in southern Africa.

The main climatic parameters of sunshine, temperature, precipitation, humidity and evapotransporation vary, with the annual migration of the ITCZ (Windmeijer & Andriesse 1993). In general there is a north-south gradient in the values of these parameters. For the purpose of this study we restrict ourselves to describing patterns of rainfall, since this will be sufficient to understand the regional and temporal variation in climatic parameters.

### Rainfall

The Rice and Mangrove Ecoregion has a monomodal rainfall regime, characterised by one single peak in rainfall during the course of a year. After the start of the rains, it gradually increases in amount and frequency, reaching its maximum in August/September. To illustrate the variation in annual rainfall in the study region we present annual data for a selection of six meteorological stations between 1960 and 2000 (see figure 2.2). A spatial impression is given in map 2.1. There is a steep gradient in rainfall with high average values in the south (Conakry: 3800 mm ± 640 ) and rather low values in the north (Kaolack: 600 mm ± 161). Note that evaporation is also higher in the north than in the south (Cormier-Salem 1999). Periods that can be characterised as 'wet' or 'dry' occur more or less synchronously in the region, but the dry periods are somewhat less apparent in Conakry. For some stations a year may be characterised as dry, while the other stations had normal rainfall. Thus, the variation in rainfall is significantly correlated between the stations presented in figure 2.2, but the correlation is not very strong (r ranges between 0.5 and 0.7). This fits with the observation by Zwarts *et al.* (in prep.) that the rainfall within the Sahel countries is rather well synchronised along the east-west gradient, but that there is less synchronisation between the Sahel, Soudan and Guinea zone.

**Map 2.1. Regional variation in rainfall (mm) in the study area, and geographical position of the six meteorological stations for which data have been used to produce figure 2.2 (source: www.fews.net)**


16°0'0"W
12°0'0"W
12°0'0"N
Senegal
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Mali
Gambia
Banjul-Yundum
Ziguinchor
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Bissau
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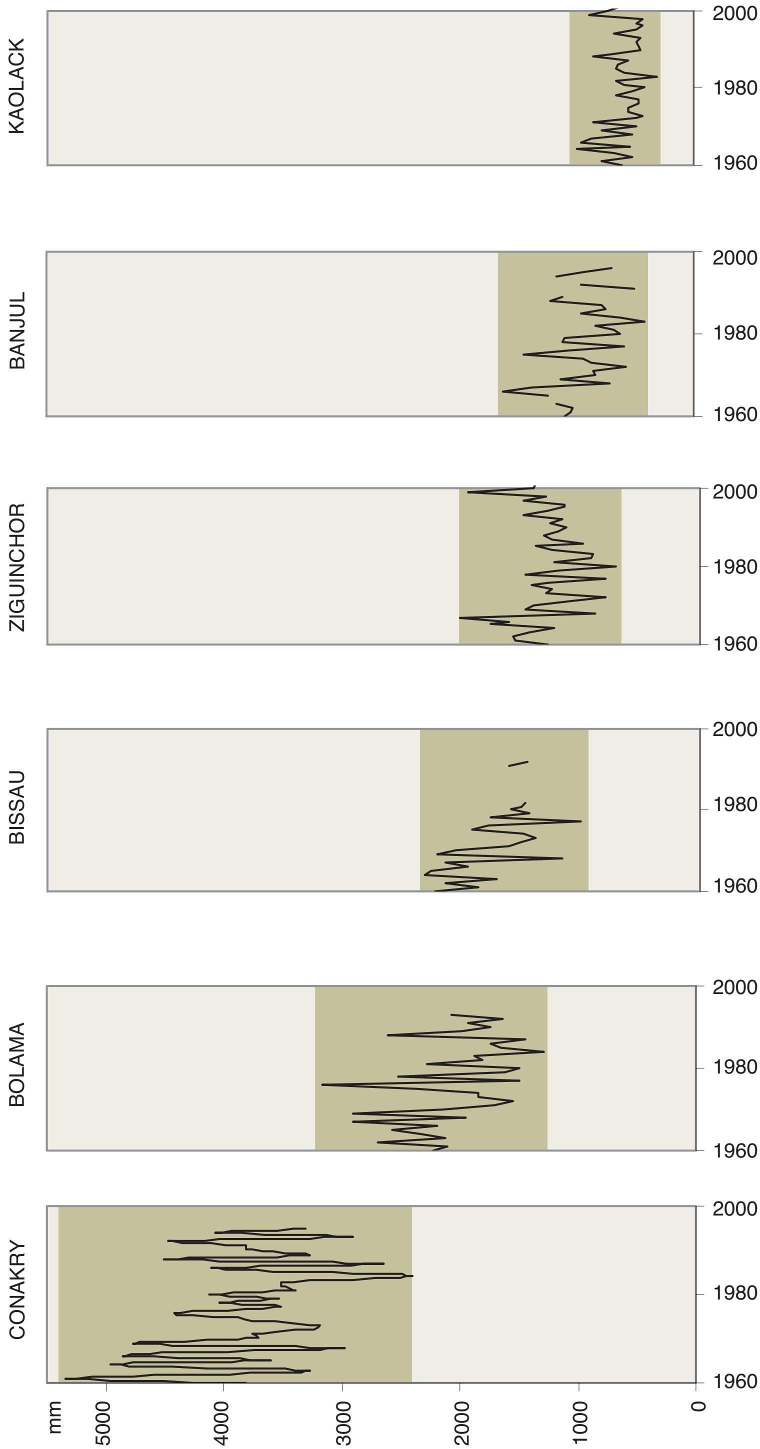


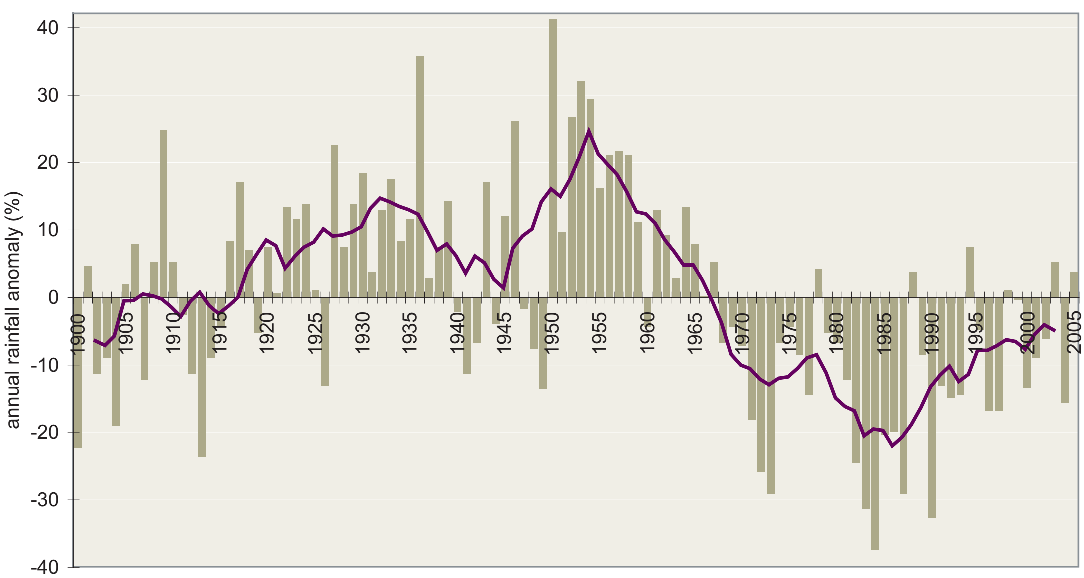

**Figure 2.2** Regional and annual variation in rainfall between 1960 and 2000 for 6 meteorological stations in the study area. Modified from Cormier *et al.* (1999)

Overall the following pattern in wet and dry years can be distinguished: Between 1961-67, many stations experienced above average rainfall. Dry periods occurred between 1972-73 and 1980-1984. These periods are referred to as the Sahelian drought. As described by Zwarts *et al.* (in prep.). for the Sahel, there appears to be a recovery in the rainfall over the last years of the nineties and early 2000. Zwarts *et al.* (in prep.) first ascertained that the fluctuations in the rainfall in the Sahel may be described with one single rain index, and concluded that for the actual Sahel zone this is indeed the case. Their result is given in figure. 2.3. The rainfall is expressed with respect to the average calculated over the entire 20th century. Many papers give the anomalies relative to the 1961-1990 average. Since the average rainfall in the Sahel, calculated over the entire 20th century is 10% higher than for the period 1961-1990, one has to move the y-axis 10% downwards to read the data in Fig. 2.3 as departure from the 1961-1990 average. Since the Sahelian drought, the rainfall has gradually improved, but it has not yet returned to the last pre-drought levels.

## River Hydrology and Salinity

Within the region, there is large variation between estuaries. Some rivers have extensive catchment areas, such as the Gambia river, while others have not, such as the Saloum and the Casamance (see map 1). The rivers in the region are generally short. Many originate in the nearby Fouta-Djallon mountains, such as the Gambia, the Corubal, and the Konkouré. Others do not, such as the Sine, the Saloum and the Casamance. The river flow is correlated to the gradient in rainfall from north to south. Therefore, there is a lot of difference in the amount

**Fig. 2.3. The annual rainfall in the Sahel (1900-2005) expressed as percentage departure from the average calculated over the entire 20th century. The smooth curve gives the 9-year running mean (from Zwarts *et al.* in prep.).**



of fresh water passing by a given location between northern and southern estuaries and between those with large and small catchment areas. The dry period in the early 1980s (see above) has manifested itself in rising salinity levels, a lowering of the tidal limits and a movement of the boundary between fresh and salt water far upstream. In the so-called 'inverse estuaries' in particular, the salinity levels upstream rose very steeply. Inverse estuaries are characterised by an inverse salinity gradient during parts of the year. Where in 'normal' estuaries the salinity gradually decreases from the river mouth in an upstream direction, this is the opposite in an inverse estuary. It develops when the tidal mixing and the flow of fresh water are insufficient to compensate for a high rate of evaporation. Examples are the estuaries of the Saloum and the Casamance, in the north of the study area. The Bintang Bolon, a branch of the river Gambia, very likely also has the conditions to develop an inverse salinity gradient. As mentioned, these conditions deteriorated during the years of drought. Flow of fresh water declined, evaporation rate increased and as a consequence, salinity levels went up. This happened especially in the northern estuaries (north of River Mansoa, see figure 2.4). As we shall see in the following paragraphs, it is there that a rapid increase in bare areas has been observed, at the expense of mangrove vegetation (Diop 1990; Diop *et al.* 1997; Cormier-Salem 1999).

# 2.3 Soils

The properties of the soils in the study area are very important for our understanding of the system, and very well described in Dent (1984) and Dent & Dawson (1999). The major constraints for rice cultivation in the mangrove zone are the salinity and the potential acidity of the soils (Cormier-Salem 1999).

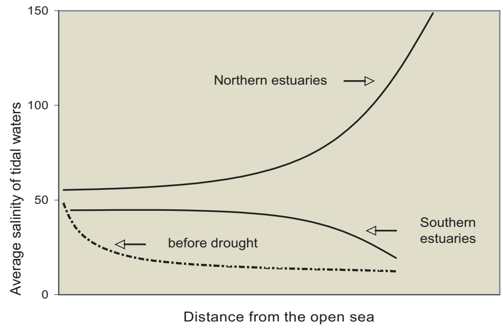



**Figure 2.4 An ecologically significant phenomenon is the difference between northern & southern estuaries, and the inward movement of high levels of salinity with the reduced river flow during drought. A normal gradient (in the south ) shows a quick decline in salinity moving upstream. Northern estuaries are confronted with hyper-salinity inland (Bertrand 1999).**

## Soil salinity

The soils may turn saline, when the fresh water supply is insufficient to wash away the salts that are present. Salinity hampers the development of plants, and thus it is of great importance to wash away excess salt before the growing season. Salts are present in the soil because they are of marine origin. Depending on the type of rice cultivation, they are still under marine influence. In some types of rice cultivation, salt water is allowed to enter the fields after the growing season. We will elaborate upon the types of rice cultivation and the management of water below, in paragraph 2.5. For now it is important to realise that salinity may affect the harvest of rice if the levels rise too much during the growing season. This can happen either by undesired salt water entering the fields from the estuary, or by capillary rise from deeper soil layers.

## Soil acidity

On the other hand, the soils may turn acid, when managed improperly. This phenomenon also causes great physiological stress to plants and hampers or even prevents crop production. Besides that, the acids produced may lead to corrosion of steel and concrete, and the poisoning of fish and livestock. Generations of people depending on soils with this characteristic have been impoverished and probably even poisoned by their own drinking water (Dent & Dawson 1999). All of this warrants special attention to the process of soil acidification.

The acidification problem is typical for mangrove soils and other soils that have accumulated lots of pyrite. Pyrite, ($FeS_2$), accumulates in waterlogged soils that are both rich in organic matter and flushed by dissolved sulphate, usually from sea water. These soil types are known as 'potentially acid sulphate soils' or 'acid sulphate soils'. According to Dent & Dawson (1999) they are the 'nastiest soils in the world'. When drained, potentially acid sulphate soils generate sulphuric acid that leaks into drainage and floodwaters, dissolves iron and aluminium from soil minerals, and thus causes the problems described above. The hazard presented by acid sulphate soils is magnified by their location - mostly in coastal wetlands where development pressures are intense.

Sulphuric acid is produced by the drainage of sulphidic mud that accumulates in tidal soils under mangrove or salt marsh vegetation. Sulphides are stable under waterlogged conditions, but drainage or excavation introduces oxygen into these materials. This oxygen oxidizes sulphides into sulphuric acid. Consequently, the potential acid sulphate soil becomes an active acid sulphate soil. Under these conditions natural vegetation is limited, the range of crops that can be grown is severely restricted, and yields are low (Dent 1984).

The reported extent of acid sulphate soils for our study region is in the order of millions of hectares, and summarised by Dent & Dawson (1999). This does not imply that problems with acidity will occur everywhere. The spatial variability is high (Sylla *et al.* 1996) and one can find locations, for example large parts of the coastal plain near Koba[1] in Guinea, where soils are not potentially acid (Cormier-Salem 1999).

Given these soil properties, the hydrology is of crucial importance. When the soil is waterlogged or under a tidal influence, the level of acidity is not apparent. Under changing hydrological circumstances however, the soil may ripen and the acidity may increase. This process occurs under natural circumstances, when the soil elevation increases due to sedimentation, and natural tidal flooding decreases in frequency. In the landscape, such areas are observed behind the mangrove formations (Cormier-Salem 1999) as bare or vegetated uppertidal flats or swamps. We will elaborate on this vegetational succession in greater detail below, since there are more factors involved (Bertrand 1999). More importantly, however, hydrology also changes as a result of human management. In order to regulate the salinity, and to cultivate rice, hydrological measures are undertaken at different spatial scales. These management measures may have strongly adverse effects on the soil condition (Dent 1984; Sylla *et al.* 1996; Cormier-Salem 1999). In paragraph 2.5 we will elaborate upon the management of water in relation to rice cultivation, and the soil problems that have arisen in some cases.

## 2.4 Mangroves

Along the coast of West Africa, extensive mangrove forests occur. Mangroves are the tropical equivalent of the temperate salt marsh and serve a range of functions, some of which are very tangible and valuable for people. Mangroves play a role in coastal protection, as a source of wood and a habitat for exploitable animal populations. They are home to the oyster and to a considerable variety of fish species. Mangrove forests are a key landscape element in the sense that they influence ecological processes beyond their own borders. The shallow waters inside the forest are habitat for reproduction

1 Geographical locations of places mentioned in the text are given in map 2.2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of fish that spend a large part of their lives in open sea. The mangroves provide organic material as a basis for the food chains in mudflats and shallow coastal waters. Many bird species that forage in other coastal habitats, use the mangroves for nesting, shelter, and roosting during the night or high tide. Worldwide, mangrove forests are under great pressure (Wilkie & Fortuna 2003). There is common global interest to counteract the observed decline in the area covered by mangroves.

The main abiotic factors that affect mangroves are sedimentation, subsoil, river dynamics, type of estuary, influence of the ocean and climate (Cormier-Salem 1999). In the study region there is a great diversity in mangrove environments, defined by different combinations of these factors. There are very sheltered sites, and sites that are very exposed to wave action. Near the mouths of the rivers there are sites with quite constant salinity of the water, whereas upstream of the 'inverse estuaries' (see paragraph 2.2) salinity may rise to levels that trees can scarcely tolerate. The diversity in tree species is however limited. There are only nine woody species, five of which are actually abundant. The structuring of mangrove populations, in relation to each of the factors mentioned, is subject of scientific debate (Bertrand 1999). Some generalisations can however be made.

**Hydrological works at different scales**

**a) Small earthen ridge (now open to let water pass) separating ricefields from the mangroves. b) A traditional opening/valve in an earthen dike, made using a hollow trunk and fortified with branches. c) Another such traditional valve. d) Upstream part of a valley blocked with a small concrete dam; this dam is poorly repaired after being damaged, and the ricefields behind it suffer from salt intrusion (Kiang West, Gambia, 2005). e) Functional valve in a ring dike around a medium-sized polder (ca. 300 ha, Koba-Katep, Guinea Conakry 2006). f) Dam regulating waterflow to a river valley (Sinedone, Senegal 2005). g) New anti-salt dam in the Bintang Bolon near the border with The Gambia, (Boudouk, Senegal 2005).**

Tidal fluctuation plays an important indirect role in mangrove distribution. Mangroves generally grow under tidal conditions. Tidal fluctuation results in a reduction of plant-competition due to alternating wet and dry conditions. The tides bring in relatively clean water and nutrients, while exporting detritus. Propagules are also transported effectively with the water. Where evaporation is very high, tidal fluctuation washes excess salts away preventing excessively high soil salinity concentrations. Mangroves are found where salinity ranges from 0-90 ppt. Salt water is not a physical requirement for growth, but mangrove communities are seldom found in strict freshwater environments. Mangroves are dynamic vegetation communities, adapting to changing abiotic circumstances. Rivers actively erode stands of mangroves on the outer sides of all the river bends, but new stands of mangroves appear on the inner sides of these same bends where sediment builds up. However, mangroves are also able to adjust the circumstances themselves. By slowing down the speed of water, they trap sediments. The different mangrove species vary in their ability to induce sedimentation and to trap sulphur. They may thus modify the habitat for successors in the vegetational sequence (Bertrand 1999).

The mangrove communities are considered to occupy separate topographic sections of the tidal range (Bertrand 1999). *Rhizophora* species, the so-called red mangroves, (*R. mangle*, *R. racemosa*) generally occupy the low-lying seaward side. Stands with *Avicennia africana*, black mangroves, are found towards the landward margin (Cormier-Salem 1999). This is related to variations in salinity. Some species tolerate a low range of salinities, while others may tolerate a much larger range. *Rhizophora* species are found where soil salinities range between 60-65 ppt. *Avicennia* has been recorded in soil salinities greater than 90 ppt (http://www.nhmi.org/mangroves/phy.htm). As has been explained in paragraph 2.2, salinity is greatly affected by the balance between river runoff and


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tidal exchange. When river runoff started to decrease throughout the area during the climatic drought, this led to a rising of salinity profile upstream (see figure 2.4). In southern estuaries the increasing average salinity of tidal waters resulted in the replacement of *Rhizophora* species by *Avicennia*, especially higher up in the intertidal zone. In northern estuaries however, such as the Saloum and the Casamance, the salinity levels reached values above the levels tolerated by most species and several authors report a die back of mangroves (Diop 1990; Cormier-Salem 1999; Bertrand 1999), in favour of bare upper tidal areas or vegetated upper tidal flats. When the rains returned, there was recolonisation by *Avicennia sp.* (Dent pers. comm., Diop *et al.* 1997).

Behind and within mangrove stands, there are large upper tidal flats. Some of these flats are vegetated, but a large part of them is bare. Open areas within the mangroves are often referred to as 'tannes', but because different authors attach different meanings to that label, we will not commonly use it in this paper. Vegetated flats and bare intertidal or upper tidal areas are naturally part of the landscape. As a result of continuous sedimentation, natural tidal flooding is bound to cease over time in the transition zone towards the upland. These are the inner margins of the forest. As a consequence, mangroves are faced with reduced input of nutrients, larger variations in salinity, water deficit and, potentially, soil-acidification (see paragraph 2.3 above). Under these conditions the mangroves naturally die back. Depending on water availability during the dry season, bare or vegetated upper tidal flats are formed. Characteristic species of the vegetated flats are *Paspalum vaginatum, Scirpus littoralis, Sesuvium portulacastrum* and, under some conditions *Sporobolis robustus.* When abundant groundwater seepage balances summer evaporation, the vegetation may change towards supertidal freshwater swamps (Bertrand 1999).

**a) Wooden bridge over a tidal gully: In the absence of dams or proper bridges, access and transport to remote villages is dangerous and restricted (Bintimodia, Guinea 2006) b, c) Functional valves in ring dikes around medium-sized polders (Douprou and Koba, Guinea 2006) d, e) Large scale anti-salt barrage constructed in 1987, which appears to have functioned until 2004 (Affiniam, Senegal 2005).**

## 2.5 Rice culture

### Five different rice ' ecologies'

Depending on the position in the landscape and the availability of water, there are several types of rice cultivation that are prevalent in West Africa (Andriesse & Fresco 1991; Anonymous 2000). Rice-culture may be exclusively rain-fed or subject to water from groundwater flows, irrigation and river-flooding as well (see figure 2.5). The West African Rice Development Association (WARDA) distinguishes five rice 'ecologies': 1) the rain-fed upland rice, 2) the lowland irrigated rice, 3) the lowland rain-fed rice, 4) the deepwater floating rice and 5) the mangrove-swamp rice. Rain-fed upland rice is planted on the slopes of an undulating landscape, where no effort is made to supply water and where there is no natural flooding of the land. Water supply is restricted to rainfall and the rice is never inundated. Irrigated rice, on the contrary, is supplied with adequate water throughout the growing season. It is only possible where a permanent source of fresh water is available. Outside our study area, for example, it is found in large areas in the valleys of the Senegal and the Niger. There, the existence of large dams (Diama, Markala and Sélingué) allow for this type of rice cultivation. Within our study area, it is practised on a limited scale, such as in the plains of Koba in Guinea (see map 2.2), where water is derived from a small reservoir. Upstream in The Gambia, farmers irrigate some 1500 ha of rice with surface water, primarily derived from the Gambia River (Verkerk & van Rens 2005). Lowland rain-fed







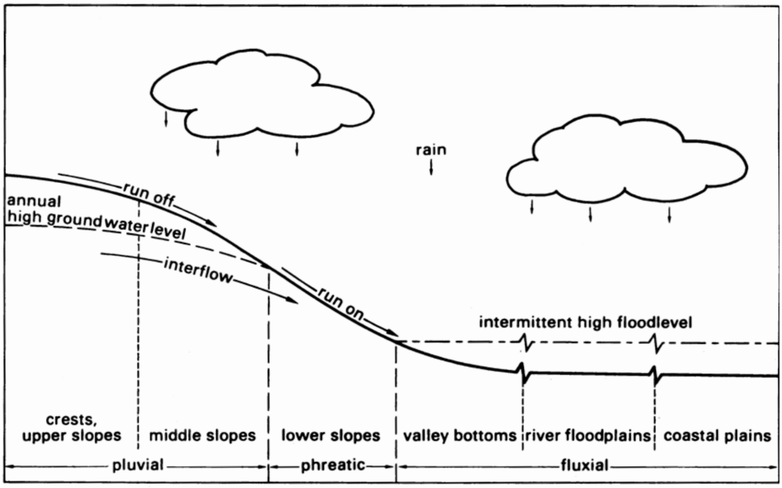




Figure 2.5 Landscape elements and physio-hydrography along a toposequence (from Andriesse and Fresco (1991)).

rice refers to rice that is cultivated in valley-bottoms, floodplains or coastal plains (see figure 2.5). Depending on the degree of control over water, these areas are said to be either managed or unmanaged. In lowland rain-fed rice, water supply to rice plants is principally provided by rainfall, run-off water, and underground water. The rain-fed lowland rice fields are usually surrounded by small earthen dikes. The dikes serve to retain floodwaters, as well as rainwater, which falls during the growing season. The deepwater floating rice hardly occurs in our study area. It refers to rice in areas behind river levees that are often flooded to large depths (sometimes several metres). Mangrove swamp rice, to conclude this description, is rice planted in tidal wetlands. Outside West Africa, this rice type is referred to as ‘ tidal rice’. Soils are flooded due to the influence of the ocean tides and/or the discharge of rivers into the ocean during periods of high discharge. The mangrove-swamp rice ecology is characterised by the alternating presence of fresh and saline water (Bayo 2003).

A special form of rain-fed lowland rice is a ‘modified tidal rice’ (D. Dent pers. comm.). This occurs where a tidal influence has been blocked, for instance because of a salt dam. This type of rice growing has a freshwater rice ecology, where there used to be mangrove-swamp rice. Because it is often developed on former mangrove soil, there is a risk of acidification (see paragraph 2.2). Modified tidal rice is therefore only possible where soils are not potentially acid sulphate (PAS), where drainage is possible without turning the soil into an acid sulphate soil (ASS). In such a situation rice production may be enhanced by reducing salt stress. There are, however, also examples where such agro-hydrological interventions have failed due to acidification. This will be discussed in paragraph 2.5.

In this study we are mainly interested in the mangrove-swamp rice, the lowland irrigated rice, and the lowland rain-fed rice. These rice-ecologies are characterised by wet conditions in the dry season and are thus of importance to wetland-related birds. In terms of area, irrigated lowland rice is not important in this study region, as compared to mangrove-swamp rice and lowland rain-fed rice (Anonymous 2000; Bayo 2003). In a following paragraph we will elaborate upon mangrove-swamp rice cultivation in greater detail.

## Mangrove swamp rice

To understand the range of strategies to grow rice in the mangrove zone, one has to consider the major ecological constraints. In order of importance they are 1) the availability of fresh water, 2) the phenomena of salinisation and acidification, 3) the stability of the sediments and 4) the predators of rice (Cormier-Salem 1999). Here, we will outline the essential aspects.

Rice is sensitive to salt, but salt and salt water are present everywhere in this zone. To manage the fresh and salt water there are two principal systems (see figure 2.6). In its most simple form, the rice fields are open, and the rice is flooded by fresh river water (panel B, figure 2.6). This culture is possible when the flow of the river is large, bringing so much fresh water during the growing season that salt water from the sea does not affect the culture. The fields are flooded daily, and water management is absent. Other forms of rice cultivation, prevalent throughout the region, make use of dikes. The dikes keep the fresh rain water in and limit the entrance of salt water during the growing season (panel A, figure 2.6). In traditional systems the dikes are small, but modern forms have a large 'ring dike' that encloses several hundreds of hectares, and channels to better manage the water levels (Diop 1990; Cormier-Salem 1999; Bayo 2003).

A good management of water provides optimum conditions for growth of rice. Rice grows best in a permanent layer of water. At the same time the farmers have to try to maintain soil productivity, fight weeds and be able to work on the land during planting and harvesting. Control over water is essential for all of this, and we will illustrate that by describing one of the typical forms of cultivating mangrove swamp rice in more detail.

## Mangrove swamp rice cultivation

Per year there is only one cycle in the rice culture. Rice is generally transplanted as young plants during the rainy season, and harvested in the dry season[2]. During the non-growing season, salt water is allowed to enter the rice-fields. Flooding with salt water prevents acidification (Dent 1984; Cormier-Salem 1999; Dent & Dawson 1999). According to the literature, the system of cultivating rice would not be sustainable in the mangrove zone without this flooding with salt water, especially not where soils are potentially acid sulphate. It is necessary to maintain waterlogged conditions in potentially acid sulphate soils, as has been explained in paragraph 2.3, otherwise the soil acidity may become excessively high. But even in soils that do not turn acid under drainage, there are advantages in the sense that salt water kills weeds and brings in nutrients. Besides, in some places it is very impractical or even impossible to prevent salt water from entering the fields during the non-growing season. At the beginning of the growing season fresh water is used to wash away the salts that have accumulated, and to provide water for the plants. To flush the polders, there are valves in the dikes. In the traditional system these are made of hollow trunks, modern forms are made of concrete and steel. Before planting the fields are prepared using a special spade that is suitable for working the heavy clay soils (see photo page 33). By turning the soil and creating small ridges, weeds are killed, soils are flushed from salts and acids more quickly, and the fertility of the soil is enhanced. Then, when excess salts (and acids) have been flushed, the valves are closed and fresh water is allowed to accumulate in the polder. In practice it is extremely difficult to find the right balance everywhere between flushing with fresh water and maintaining sufficient reserves of water for completing the growing cycle. This is especially true where water levels are managed over larger areas with some variation in topography. The need to store fresh water and the risk of salt intrusion vary from north to south in the eco region, and so does the use of dikes and ridges. Where soils are flushed quickly anyway, there is no need for ridges. And when the risk of salt intrusion is low, there is no need for protective dikes. Under these conditions the rice fields are open as in panel B, figure 2.6. Large areas of this type are found in the River Gambia around kilometre point 170, the middle part of the country, and in certain plains in the upper parts of estuaries in Guinea and Sierra Leone.

The availability of fresh water is high in Guinea and Sierra Leone, but low in Senegal, The Gambia and the northern part of Guinea-Bissau (see paragraph 2.2). Both situations are problematic. The rainfall conditions are, on the other hand, ideal in the south of Guinea-Bissau, leading to harvests of circa 2

2 Under some conditions, such as the tidal rice in the Gambia, the rice is planted later.

Earthen dikes are created and maintained with manual force in the traditional system, using a specially adapted spade, suitable for this type of soil. The tool, handled here by Mr. Mario da Silva, is up to four meters long, strong, and able to cut the clay.

tonnes per ha per year (Cormier-Salem 1999). It is clear that a proper water management requires dikes, drains and valves. The maintenance of such structures is complicated and labour-intensive in the zone, where erosion and sedimentation are powerful forces. To complicate things further, the water should preferably circulate. Circulation of water has several advantages, amongst which is the reduction of disease. Finally, the rice growers have to deal with crabs, fish and birds, as predators of rice. Crabs also cause damage to the earthen dikes (Cormier-Salem 1999). Rice cultivation in the mangrove zone is a low-input type of cultivation. The farmers only rarely have the means to pay for fertilisers or pesticides (Cormier-Salem 1999). Notwithstanding these difficulties, the local populations have been-able for centuries to produce rice and they are stil-

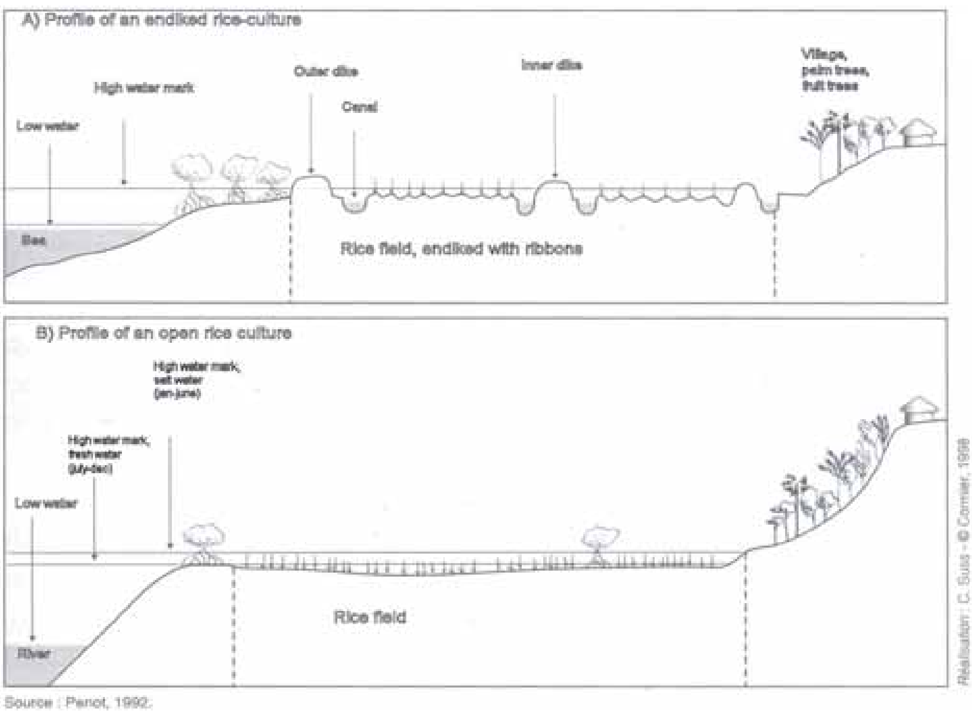


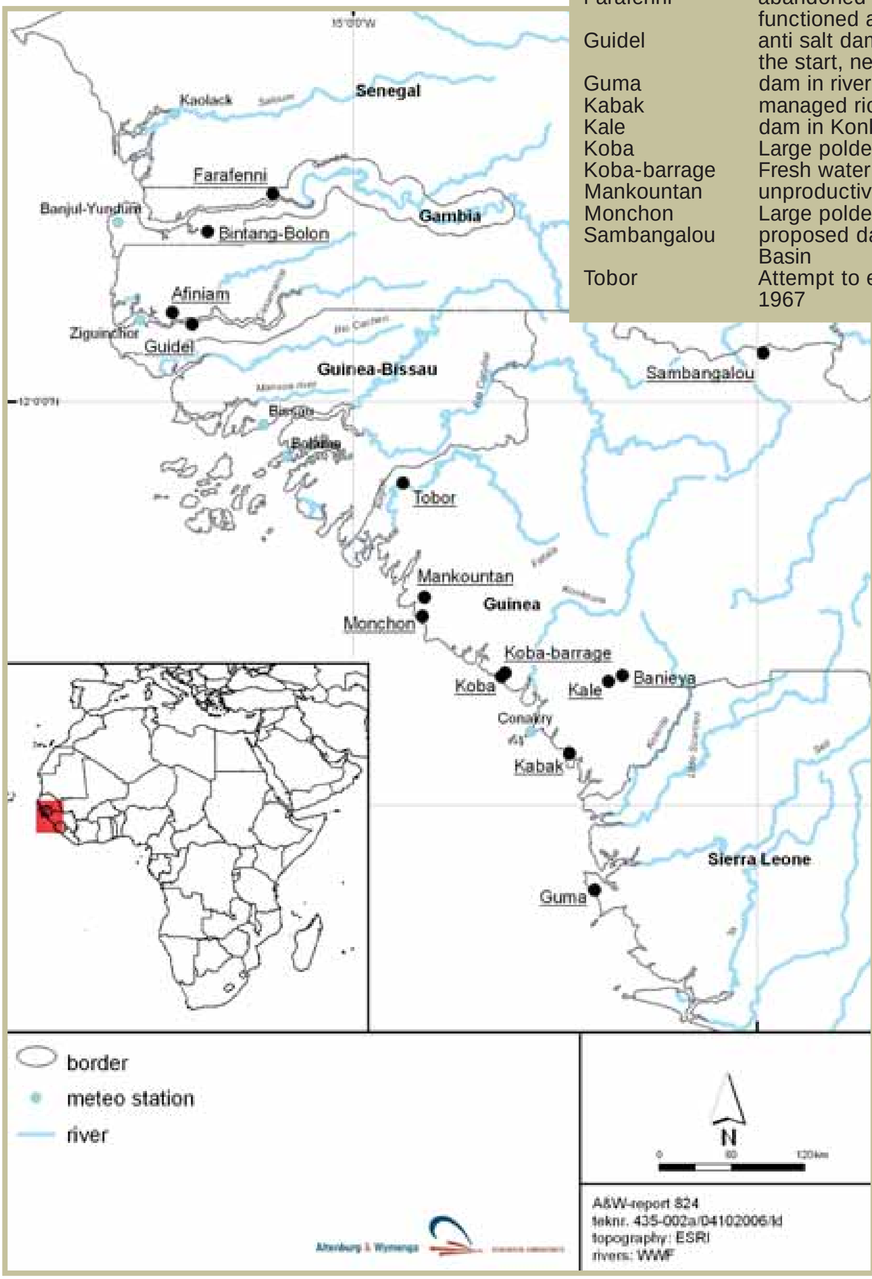

**Figure 2.6. Profile of the two principal systems of rice cultivation in the mangrove zone (from Cormier-Salem *et al.* 1999). Panel A) Profile of an endiked culture, B) profile of an open rice culture.**

doing so with great skill and knowledge. Interventions to improve rice production have been many, but one of the key lessons learned has been to use that local knowledge carefully (Diop 1990).

## Other natural vegetation in the lowlands

On a landscape scale, the areas that are characterised as rice complexes are in fact a mosaic of different vegetation communities. Within a rice complex there are parcels that are either unsuitable for cultivation, or which are temporarily uncultivated. Some of these communities are temporarily fresh water habitat, e.g. wild rice and aquatic vegetation *(Nymphea, Nunephar)*. Other communities can be characterised as more or less salt-tolerant. Examples of the latter are the Cyper vegetations (e.g. *Scirpus littoralis*), grass stands (*Sporobolus robustus, Paspalum vaginatum*) or communities dominated by *Sesuvium portulacastrum* that also occur on upper tidal flats. In this report we use the term 'other natural vegetation inthe lowlands' to refer to plant communities other than rice or mangrove vegetation (or riparian forest). To summarise, they are low-growing vegetation types occurring on upper tidal areas, in valleys, behind dams or within rice-polders.

| Label | Remark |
|---|---|
| Affiniam | Anti-salt dam, 1980 |
| Banieya | dam in Konkouré basin, 1969 |
| Bintang-Bolon | branch of The Gambia |
| Farafenni | abandoned cultivation, dam has functioned a few years |
| Guidel | anti salt dam- failed almost from the start, near Niaguis |
| Guma | dam in river Guma, 1966 |
| Kabak | managed rice fields |
| Kale | dam in Konkouré basin, 1963 |
| Koba | Large polder complex |
| Koba-barrage | Fresh water reservoir |
| Mankountan | unproductive area |
| Monchon | Large polder complex |
| Sambangalou | proposed dam in Gambia River Basin |
| Tobor | Attempt to establish large polder 1967 |




**Map 2.2. The geographical location of some of the major agro-hydrological works in the eco-region and other places mentioned in the text. With regard to the agro-hydrological works, note that the overview is not exhaustive. A small remark is given for each location in the associated table, but for more explanation we refer to the text.**

### Overview of agro-hydrological interventions

The policy of each West-African country for the last decades has been to reduce the dependency on rice imports and thus to increase the domestic rice production. For this purpose a suit of larger dikes and dams have been built. On the one hand large managed polders (over 1000 ha) have been implemented e.g. in Koba (1950 - 1990), Guinea or Tobor, Senegal (ILACO 1967, see map 2.2 for the geographical locations of places mentioned in the text). The first experiences on large scale in the Casamance, to improve production by enhanced desalinisation (ILACO 1967), were negative due to negligence of the phenomenon of acidification. This occurred before our study period. Also, large dams have been erected to regulate the salt water into entire valley systems. By allowing for salt water to enter during the non-growing season, one aimed to copy the local strategy of managing the water. Important examples are the dams in the Casamance near Affiniam (1987), which was functioning until 2004, and Guidel (1983), which failed due to acidification.

Seen on the continental scale, the amount and density of large dams in the region are limited. In an overview of dams in Africa by the FAO (aquastat, www.fao.org/geonetwork) only three dams appear in our study area, out of 1138 in the continent as a whole. These are the Banieya Dam and the Kale Dam in the basin of the Konkouré, Guinea, and the Guma Dam in Sierra Leone. All three were built in the 1960s. The other dams mentioned above do not appear in the continental overview.

Smaller examples of agro-hydrological interventions (< 500 ha), aim at the restoration of agricultural potential in valleys with hyper-saline soils and can be found throughout the region, but especially in the Casamance. Still many of such dams are under construction, financed by USAID, FAO and the European Community. The ecological impact of these hydrological measures has been greatly dependent upon the scale, the local situation and the management of the functioning of the dams and valves. The larger polders and dams in the study region should be evaluated in economical terms, as well as in terms of rice production and biodiversity.

## 2.6 The Rice and Mangrove Ecoregion as habitat for birds

The coastal wetlands in the study area have great ornithological importance (de Naurois 1969; Altenburg 1987; Altenburg & van der Kamp 1991; Cormier-Salem 1999; Dodman *et al.* 2004). In this paragraph we will elaborate upon the characteristics of the main habitats, and their seasonality.

### Rice fields

The rice cultures are large-scale, predictable fresh water habitats, where water is available far into the dry season. The farmers actively strive to keep their fields submerged in order to obtain the best conditions for the growth of rice. In the fields, birds can forage and find different sources of food. Food availability is not constant, but rather changes during the season both in type and abundance. When the rice has been seeded it could potentially provide a source of food for birds, such as the Black-tailed Godwit. However, in this region farmers usually transplant older plants in order to prevent this kind of predation, especially by the abundant crabs. During the growing season the rice fields contain water, with levels down to 1m deep. The shallow water and the channels in between the fields contain small fish and invertebrates that disappear when the fields dry out before or during the harvest. These animals are prey for herons, waders and kingfishers and before the fields dry out, they become very easy to catch. As the rice matures, the fields become a habitat for birds that feed on insects and seeds. Seed-eating birds are a huge problem for farmers (*Quelea sp,. Ploceus sp.*), who, or whose children, in some places have to watch the fields continuously or they risk significant damage. The first rice is harvested in November, but the harvest continues until deep into the dry season, depending on the local hydrology. After the harvest, the fields temporarily are a good feeding habitat for many waders and herons that search for fish, invertebrates or remaining rice grains. For the remainder of the dry season, the fields are either dry and very poor in food availability, or tidally submerged with salt water.

### Bare uppertidal flats

The bare upper tidal flats provide a very open habitat. The flats are poor in forage availability at the end of the dry season, because the levels of salinity and acidity may be extreme. Some birds, such as Spur-winged Lapwing use these areas for nesting during this season. However, during the wet season the flats become moist, the levels of acid and salt go down, and forage availability increases in the form of soil-dwelling invertebrates. During that time the flats are habitat for important numbers of migratory species associated with salty conditions, such as common Greenshank, Black-winged Stilt, Bar-tailed Godwit, Whimbrel and *Calidris* sp. (Zwarts 1988).

### Other natural vegetation in the lowlands

The vegetated flats and the fresh water vegetations within rice complexes serve similar functions for birds, as has been described above for the rice fields and the bare uppertidal flats. As long as water is available there is potential for feeding on insects, fish and invertebrates. Depending on the plant community (think of the grasses) there might also be seed available for food. However, towards the end of the dry season water will tend to disappear and food availability will decline. The deeper water bodies within rice-complexes, or behind dams, will keep fresh water for very long periods. These water bodies are often characterised by aquatic vegetation. They are important for a great diversity of wetland-related birds, of which African Jacana and White-faced Whistling Duck might serve as examples.

### Mangroves

Many bird species that forage in the above-mentioned coastal habitats, use the mangroves for nesting, shelter, and roosting. Out of 125 species observed in the mangroves in a study by Altenburg & van Spanje (1989) only a relatively small number of species have been observed often. The available food for birds consists of insects, fish and crabs. In line with that, Altenburg & van Spanje list nine insect eating birds, three mainly fish- and insect-eating kingfishers and two crab-eating waders for which they assume that they stay largely within the mangroves. Examples are the Reed warbler, Whimbrel and Common Sandpiper. They also list three other insect-eating species, e.g. the Green Bee-eater, and the seed-eating *Ploceus cucullatus*, as occurring 'very frequently', but which forage elsewhere as well to a large extent. Mangroves are considered a 'key-habitat' nonetheless for many more birds in the coastal wetland system, because of the thick cover and poor accessibility, offering safe res-ting places.

### The whole is more than the sum of the parts

Above, we have discussed the value of individual classes of habitat. It may be clear that the boundary between these types of wetland is never distinct and the majority of bird species is not restricted to any one of them. Some groups of species have not been mentioned above, because they do not link to any of the habitats specifically. Think of some of the raptors of open terrain (Harriers, Kites), fish eating raptors (African River Eagle, Osprey), or aerial hunters of insects. There are also many species that are not specifically wetland-related, but that do occur in considerable numbers, such as pigeons and doves. The coastal wetlands in the region are a diverse entity.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# 3

# Methods

In the current study, we aim to quantify the availability of different wetland habitats for birds and the changes in surface kinds that have occurred over the past 15-20 years. We also aim to investigate the composition of the bird populations in the different wetland types and the occurrence of threats to these systems. To do so, we use several sources of information. Mainly we rely on field information collected for this purpose during a series of field missions, remotely sensed information on current land cover, old maps, and literature. The necessary information regarding the different methodologies is gathered in the following sections of this chapter.

## 3.1 Remote Sensing

To estimate the surface of the wetland habitats in which we were interested, a series of maps were created for early 2000. This was done using remote sensing, in combination with field surveys. We used Landsat Thematic Mapper images for the entire region (10 scenes), which were carefully selected for appropriate moment in time and cloud cover. The aim was to obtain images for two moments in the rice-growing season, but for only for five out of ten possible scenes, did we manage to do so (see appendix 2). The images were all cloud free and either refer to the year 2002 or 2003. The images were transformed into land cover maps using training sites collected during field surveys in 2004 and 2005. This process of transforming images into maps is called classification. An image consists of multiple pixels. In the case of Landsat TM images, these pixels measure approximately 30 m by 30 m. For each pixel the satellite has recorded values for the reflection of green, blue, red and infrared light. These are the so-called bands 3, 4, 5 and 6. Different materials reflect light in a different way, and each of the Landsat Thematic Mapper bands is tailored for detecting different features. Vegetation, for example, absorbs red light. Band 3 records red light. This band can be useful for distinguishing between vegetation and soil. Band 6 is a thermal band, which means it can be used to measure surface temperature. By combining information from different bands one can distinguish between different land cover types more or less accurately. However, in order to know which combination of values refers to which type of land cover, one has to have a set of training sites. A training site is small area, with known spatial position and for which the

**Colleagues in the field**

**a) Kadiatou Soumah explaining local people about the study. b) Bacar Coma (left) doing the same. c) Ibrahima Sory Barry, Daan Bos and Mohamed Balla Moussa Conde. d) Arnold Okoni-Williams, Joãozinho Sá and Kawsu Jammeh. e) Jan van der Kamp. f) Rob Bijlsma. g) S. Sounounou BAH. h) Rob Bijlsma and Kawsu Jammeh. i, k) Kadiatou Soumah. j) Hamilton A.B. Monteiro. l) Mamadi 3 Camara.**

land cover is also known. In our case, these data were collected in the field as will be explained below.

### Ground-truthing

The training sites, to be used for groundtruthing of the satellite images were collected during December 2004 and between November 2005 and January 2006. Along transects in the study area, we systematically noted the habitat present in spatially defined plots. The transects cover the entire altitudinal gradient. Positions were fixed using a Garmin E-Trek GPS, with an accuracy of 7m approximately. The plots range in size from 0.25 to 4.4 ha (mean 2.3 ha ± 0.2 s.e.) depending on habitat variability. The main characteristic of the habitat recorded was plant community, but in addition to that we recorded vegetation cover, cover of bare soil and soil moisture in 4 classes. The extra information helps us to understand variation in the reflectance on the images. In total 430 plots were used for training of the software, while 1569 plots were used to quantify the quality of the end product.

### Classification

Our focus was on the lowland areas, i.e. the mangroves, intertidal areas and coastal plains. The lowlands were classified into four broad land cover classes (rice-fields, mangroves, natural vegetation other than mangrove, and bare areas). We have delimited our study area from 14º 30' N to 7º 30' N and with a soil level below 30m altitude. To select areas below 30m altitude, we used a Digital Elevation Model (DEM) that was derived from radar images. Afterwards the quality of the images was assessed using a separate set of training sites (Congalton 1991; Janssen & van der Wel 1994; Comber *et al.* 2005). The quality of land cover maps may not only vary due to technical reasons, but also due to other aspects (Comber *et al.* 2005). These sources of variation are often ignored, and may severely affect the results of any analysis. We have therefore specified the quality of our map in appendix 2 in most of these terms.

The resulting classification was then used to estimate the area of each land cover class. The results were also compared to existing old maps for the period early 1980, to estimate change in surface of each wetland habitat. We will discuss the origin and quality of these maps in the next paragraph. Another source of data for the assessment of changes in land cover was the published and unpublished literature. This includes the FAO statistical database (http://www.fao.org/), which was used to obtain independent estimates on harvested area of rice and rice production in time. We did not distinguish between different rice-ecologies and neither do our other sources of data on the available area of rice. The class of 'rice fields' thus refers to both lowland rain-fed rice ánd mangrove swamp rice.

## 3.2 Old maps

The estimates of available area per habitat type from the past were obtained from existing maps. The reason for using existing maps in preference to creating new classifications based upon old images, is that we lack proper field information that relates to the old images. We can safely assume that the producers of maps at the time had better access to good quality field information than we have now. The quality of already existing maps will therefore be greater than the quality of maps that are produced *a posteriori*.

The maps found refer to years ranging from 1978 to 1993. None of the maps is supplied with quantitative information on accuracy. For Senegal and the Gambia we used the vegetation map of Senegal 1982 (Stancioff *et al.* 1986), kindly supplied by USGS EROS, South Dakota, USA. The map can be used to estimate mangrove area, but rice has not been classified as such on that map. An unpublished source for The Gambia was derived from the internet (Tyldum unpubl.) and probably refers to 1982. We also used estimates derived from the recent topographical map for the Gambia 2001 (JICA 2001), based upon aerial surveys and ground truthing. Land cover in the lowlands of Guinea-Bissau has been assessed in 1978 using remote sensing (SCET-INTERNATIONAL 1978) and was updated in 1993 (Cuq *et al.* 1996). We were allowed to reprint the maps with permission from lÚBO-CNRS, laboratory Géomer (LETG UMR 6554). For Guinea the land cover in the lowlands was assessed in 1987 using remote sensing (CCE 1990), and we had access to a paper version of that map.

### Assessment of change

Statistical trends in the extent of mangrove vegetation were calculated per country using a selection of the available estimates, following and elaborating upon Wilkie & Fortuna (2003). This was done by regression analyses of existing reliable data over time for each country. We selected those data points that were judged by Wilkie & Fortuna to be reliable, unless we were able to replace them by estimates from an even more reliable, primary, source. In addition we added our estimates from recent maps, provided that the user accuracy (user accuracy is defined below, in Chapter 4) was greater than 70%.

## 3.3 Importance for wetland-related birds

To quantify the importance of the wetlands for birds we have systematically counted birds in the different habitats. These data are used to describe the composition of the bird community, to analyse which factors are influencing bird density and finally to obtain insight in the number of birds utilising the Rice and Mangrove Ecoregion.

### Bird density counts in the lowland habitats

We obtained estimates of bird density by counting birds relative to a known surface area. These so-called bird-density counts were performed in four major classes of habitat, i.e.. 1) the rice-growing areas, 2) ‘natural vegetation in rice areas’ (often fallow lands and vegetated upper tidal areas, for a description see 2.5), (3) bare upper tidal areas and (4) mangroves. Each plot counted is considered a sample. For each plot we recorded information on the stage of the planting cycle, vegetation structure, and water availability.

The bird density counts were collected during the dry season in December 2003, December 2004, January - February 2005 and November 2005 - January 2006. In this season both the Afro-tropical and the Palaearctic migratory species are present. We sampled plots along transects in the study area. The transects cover the entire altitudinal gradient within the lowlands, except for intertidal areas and *Rhizophora* stands. The major focus has been on plots within rice-cultures (n = 2679) and ‘natural vegetation in rice areas’ (n = 168), but for comparison some information has been collected in bare upper tidal areas (n = 85) and mangroves (n = 64). Rice fields are all those areas in the lowlands where rice was or has been cultivated in the current season. The sample of mangroves is biased towards edges of mangrove areas and accessible mangrove stands. The other habitats, including the rice, may also be biased, in the sense that the drier (*i.e.* more accessible) areas are over-represented, in spite of the fact that we continuously tried to select our plots randomly in the area visited.

The majority of plots has been sampled by a core of five observers, often assisted by one or two others. A total of ten observers have assisted in collecting the field data. Observer groups often changed in composition during the fieldwork. Some observers have sampled in the entire region, while the input of others remained restricted to one or two countries.

**Black-winged Stilt**

The size of plots was assessed by measuring length and width. When the plots were enclosed by small dikes, the dikes were used as a support to define plot boundaries. The dikes often do not follow straight lines and do not meet at right angles. Therefore the plot boundaries were chosen relative to the dikes, in such a way that the surface could be estimated reliably. Alternatively, when dikes were absent, birds were counted along clearly delineated transects. Again, by measuring the length and width of this plot, the surface-area was estimated. Average plot size was 4200 $m^2$ ±103 s.e., but in the rice fields the plots tended to be a little smaller (3800 $m^2$ ±103 s.e.). The observers tried to count all the birds in the plot. To do so birds were chased by walking through the plot, while making noise, or by throwing clayclumbs. A next plot was generally situated at a distance to ensure independent sampling. For each plot information was collected on vegetation density (4 classes), vegetation height (4 classes), inundated area (5 classes), and water depth (8 classes). These parameters are considered ‘ proximate factors’ which should explain part of the observed variation in bird assemblies and bird densities.

We have restricted our observations to ‘wetland-related species’. Some groups of birds are not represented in the dataset, which may have been important in other contexts, for example seed-eating birds (Finches, Quelea, *Prinia*, Weavers, Pigeons and Doves). Raptors are not included because their abundance and their wide-ranging behaviour are

**Collared Pratincoles**

such that our method is not suitable to assess densities accurately. Note, however, that each counting method has its limitations. Our motivation for choosing density counts stems from the desire to obtain detailed, objective, and independent measures on a per area basis.

## Extrapolation to regional numbers

Given the area of rice habitat, and the average density of birds for these habitats, we extrapolated densities into numbers for the rice fields in the entire ecoregion. The available area of rice habitat was taken from the classification we made using remote sensing. Keeping in mind the potential bias towards drier areas mentioned above, we believe that there is sufficient agreement between the rice distinguished on the map, and the rice-plots for which bird densities have been calculated, to allow for such an extrapolation.

The area estimate (in hectares) has been multiplied with the estimated density per species per habitat ($no.ha^{-1}$), to obtain a regional estimate for the entire lowland zone in the study area. Confidence intervals for these regional estimates were approximated by propagating the standard errors of the mean for the density estimates, and multiplying them by 1.96 (Zar 1996). At present we are not able to include an error estimate, that relates to the estimated area of each habitat, into this propagated error.


a
b
c

# 4

# Results

## 4.1 Current landcover maps on a regional scale

The results of our image classification for 2002-03 are spatially presented in map 4.1. This map is a composite of 10 classified Landsat Images. In the appendices we present the same information on maps for each country, and give the available maps for the period 1978-86 from other sources as well.

As has been mentioned in the Methods-section, it is important to be aware of the quality of the maps used. Quality of land cover maps may vary for several reasons (Comber *et al.* 2005). Therefore, we shortly describe the technical aspects of quality, before we proceed to estimating changes in land cover in the paragraphs to come. Other aspects of quality are specified in appendix 2.

Technically speaking, the accuracy of the composite map presented in 4.1 is rather limited. The accuracy is measured as the Proportion of Correctly Classified pixels, or PCC. The overall accuracy is estimated at 58%. So, 58% of the pixels in the composite map have been correctly classified. However, some units of land cover can be distinguished better with Remote Sensing than others. To evaluate the accuracy per land cover unit, two measures are relevant, the user accuracy and the producer accuracy. These are given in the error matrix in table 4.1. In our map, for example, the mangrove areas are classified with a user accuracy of 64% (third row in table 4.1), indicating that 64% of the pixels classified as mangrove are mangrove in reality. The producer accuracy for mangroves is 74% (third column in table 4.1), indicating that 74% of the pixels of observed mangrove were also classified as mangrove. From table 4.1, one can see that mangrove areas are often confused with bare (often intertidal) areas, since many pixels that have been observed to be bare have been classified as mangrove. Rice fields are classified with a user accuracy of 51 %, and cannot be distinguished very well from bare areas and lowland natural vegetation. The error matrices for each country separately are given in appendix 2.

**(leftpage) Birds.**

**a) Black-tailed Godwits foraging in the rice fields. b) Black Heron, Sacred Ibis and Western Reef Egret resting. c) African Spoonbill in the mangroves.**

There is a considerable difference in accuracy of the classifications between the different scenes of the Landsat images (see table 4.2). The classification has been more accurate, and very acceptable in fact, in Senegal and Gambia with a PCC of 86% and 74% respectively. On the other hand, the results for Guinea are very poor, with a PCC of 30% only. For Sierra Leone, we have not been able to validate our results. The important point of this section is that one needs to be careful in using the results for Guinea and Sierra Leone in quantitative analyses.

### Causes of inaccuracy and consequences

Satellite image classifications are never 100% accurate, and there are several reasons for this. General reasons are found in the fact that communities resemble each other, at least on an image. Open stands of mangrove, at high tide, reflect the light almost like open water bodies. Cultivated rice resembles wild rice, or other natural grass vegetation. But rice becomes harvested, and natural vegetation does not. By combining images from different periods in time, e.g. before and after the harvest, one has more information available to better distinguish between such communities. When land cover units occur close together in space, they are inherently difficult to map precisely. Communities may even be in the same place at different moments in time. Because the ground truthing takes places at a different moment from when the image was taken, some error may be introduced. Consider, for example, a

Table 4.1 The error matrix for the classification presented in map 4.1. Numbers in the matrix represent numbers of pixels (sampled as clusters of pixels). For each class the correct % is added. The overall accuracy is 58%. The land cover legend units are explained in appendix 2.

| | Observed land cover | | | | | | users accuracy |
|---|---|---|---|---|---|---|---|
| Classified data | bare | mangrove | lowland natural vegetation | rice | upland | water | correct % |
| bare | 5903 | 447 | 447 | 77 | 97 | 390 | 80% |
| mangrove | 2568 | 5779 | 278 | 297 | 30 | 10 | 64% |
| lowland natural vegetation | 652 | 260 | 1589 | 722 | 151 | 40 | 47% |
| rice | 3244 | 873 | 1235 | 6538 | 779 | 29 | 51% |
| upland | 3659 | 184 | 3735 | 13573 | 24637 | 63 | 54% |
| water | 220 | 232 | 43 | 56 | 143 | 2558 | 79% |
| producers accuracy | 36% | 74% | 22% | 31% | 95% | 83% | |

Table 4.2 The overall accuracy of the classification presented in map 4.1 per country PCC = Proportion of pixels Correctly Classified. An assessment of quality for Sierra Leone is missing.

| Country | PCC |
|---|---|
| Guinea-Bissau | 61% |
| Guinea | 30% |
| Senegal | 86% |
| The Gambia | 74% |

rice field that has been abandoned for a year. This source of error can to a large extent be avoided by making careful field observations.

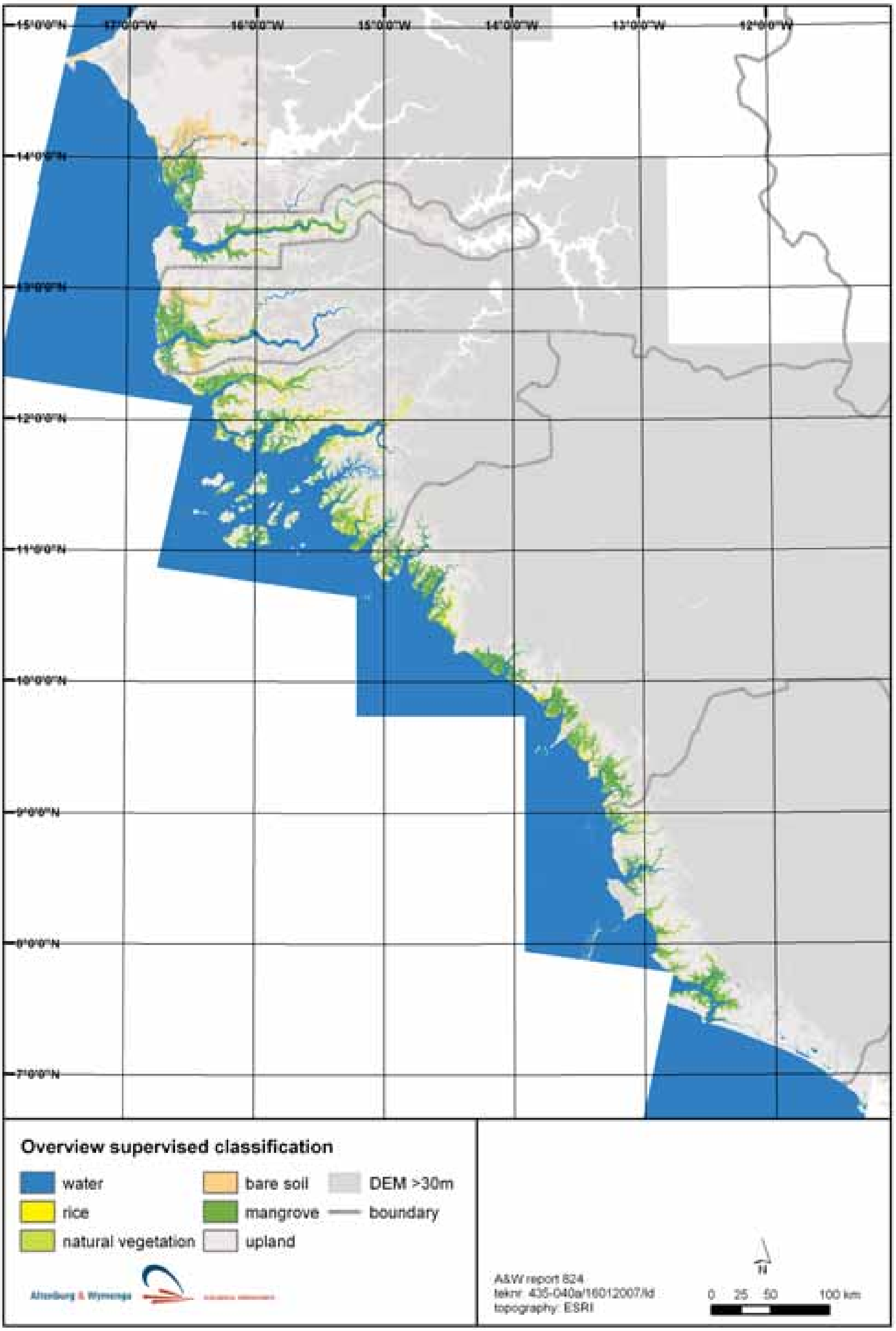
A specific reason why our results have limited accuracy is found in a limited availability of suitable images for the middle of the dry season for Guinea and Sierra Leone. In addition to that, we also failed to obtain ground truthing plots for Sierra Leone. Together these represent a severe lack of information. For the interpretation of the maps it is useful to give one further comment. The map was made to obtain an overview on a regional scale. This scale is such that, possibly, local change may not be apparent, however significant the change at that (local) scale.

## 4.2 The extent of mangroves

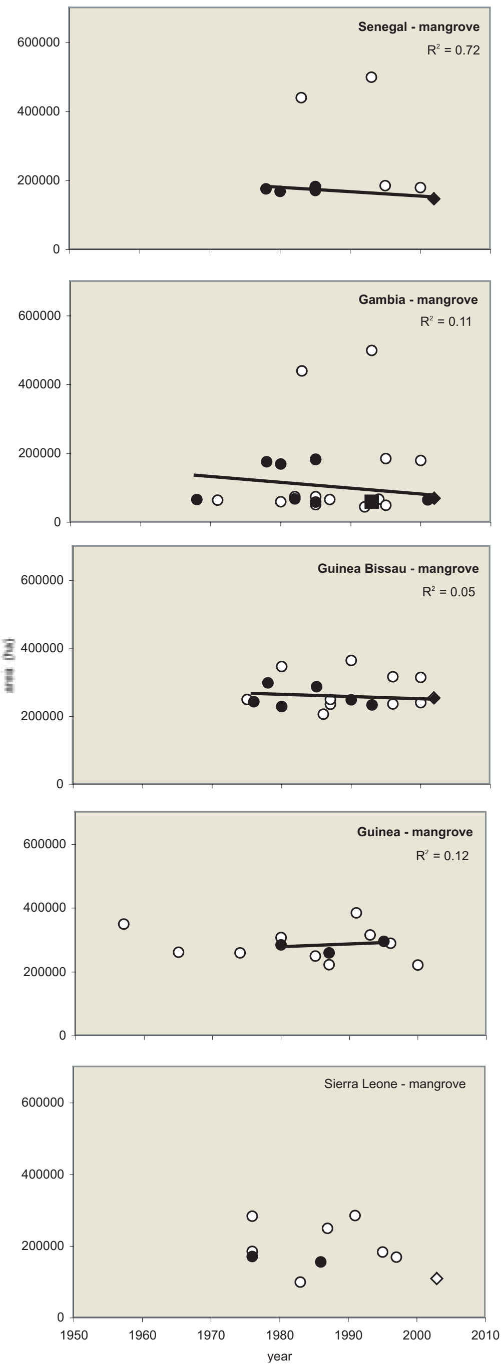
### Present area and developments over the past decades

The current extent of mangrove populations is estimated to be 795,000 hectares in our study region (2002, area south of 14º30' N and north of 7º30' N). This is about 5.3% of the world's mangrove area. In absolute terms, the majority of the mangrove vegetation in this region is found in Guinea-Bissau (32%) and Guinea (28%). There are, nonetheless, very extensive tracts in each of the other countries. In figure 4.1 we present our national estimates in relation to previous data collected by Wilkie & Fortuna (2003).

The area of mangrove in Senegal south of the line 14º30' N is estimated at 143,000 ha in 2002 (figure 4.1). In 1985 the mangroves covered 171,000 ha in the whole of Senegal, according to the map by




Map 4.1. Land cover in the lowlands of the Rice and Mangrove Ecoregion for early 2000, based upon remote sensing. The Landsat images used date from the years 2002 and 2003. Detailed representations of the same classification are given in Appendix 1.




Stancioff *et al.* (1986), with 98,9% of the area below the line 14°30' N. So, in 1985 there was 1900 ha above the line 14°30' N. Note that in figure 4.1, all estimates other than those for 2002 refer to the whole of Senegal. For calculating a trendline we therefore corrected the 2002 estimate by adding 1900 ha. Between 1985 and 2002, there is an apparent decline in mangrove area of 0.8 % per year.

Our estimate for the Gambia in 2002 is quite accurate and in line with independent estimates from the recent topographical map (JICA 2001). Currently, there is 68,000 ha of mangrove in the Gambia (figure 4.1), as compared to 59,000 ha according to the vegetation map from 1985 (Stancioff *et al.* 1986). FAO reports from that period, and before, however indicate much larger stands of mangrove (FAO 1981; Piot *et al.* 1991). Piot (1991) for example estimates the mangrove area in 1985 at 182,000 ha, based upon a ground survey. Thus it is uncertain whether there has been a decline since the early 1980s. In 1993, the area has been estimated at 60,000 ha, using aerial photography in conjunction with a ground survey (Ludwig & Bojang 1998). This means that, at least for the last decade, the situation is stable in terms of surface area.
For Guinea Bissau, the most recent national estimate of mangrove area is 252,000 ha in 2003 (this study, figure 4.1).

**Figure 4.1 Available estimates of surface area covered by mangrove vegetation per country. Trend lines are calculated using a selection of available reliable estimates (black markers), following Wilkie & Fortuna (2003). Diamond shaped markers refer to estimates derived with Remote Sensing in this study. Data and sources are given in appendix 3. Note that the estimate for Senegal for 2002 refers to the area below the line 14°30' N plus 1900 ha to correct for the fact that all other estimates refer to the country as a whole. The Sierra Leone estimate for 2003 is limited to the area north of 7°30' N.**

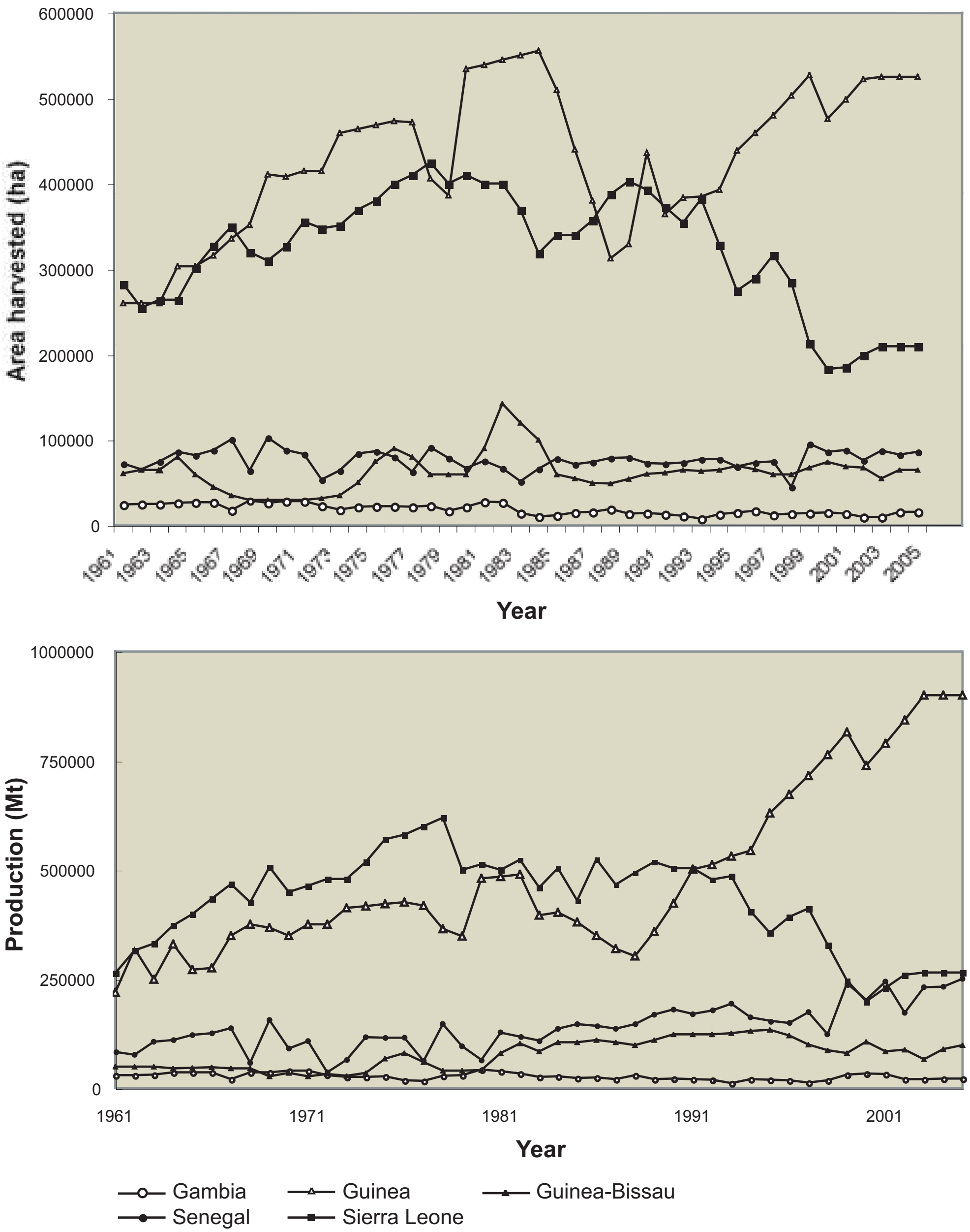



Figure 4.2. Rice cultivation in the countries of Rice and Mangrove Ecoregion, A) the area harvested and B) the total production of paddy rice per country. (FAOSTAT data, 2006, last accessed May 2006).

The user accuracy of this mangrove estimate is 70% (appendix 2), which is lower than for Senegal and the Gambia, which had user accuracies for mangrove of 84 and 95% respectively, but which is nonetheless acceptable. The estimate is a little higher than previous estimates for 1993 and 1990 (CIRAD-Forêt 1992; Cuq *et al.* 1996). For the early 1980s the estimates that were considered reliable by Wilkie and Fortuna (2003) range between 230,000 and 299,000 hectares. Given this existing variation between estimates for a given time frame, it is not possible to distinguish subtle trends. A large-scale trend, however, is absent for Guinea Bissau.

We do not have reliable recent estimates for Guinea and Sierra Leone. The user-accuracy for mangroves in Guinea in 2002 is 33% (appendix 2). For Sierra Leone the classification has not been validated. Our estimates for mangrove area (the open diamond-shaped markers in figure 4.1) rank among the lower values for these countries, which suggests that there might have been some decline since the 1980s. The estimates that were considered reliable by Wilkie and Fortuna (2003) range between 260,000 (SECA/CML 1987) and 296,000 (Saenger & Bellan 1995) for Guinea and between 156,000 and 171,000 ha for Sierra Leone (FAO 1979; Laumans 1996).

## 4.3 The extent of rice fields in the mangrove zone

### FAO statistics

The developments in rice cultivation in West Africa are documented by FAO on a per country basis. Not all of the rice covered with these statistics relates to mangrove swamp rice or other lowland rice ecologies, but we may nonetheless use the data to sketch the general development. FAO statistics refer to ‘paddy rice’. In general, rice is grown in paddies, flooded parcels of arable land used for growing rice (http://en.wikipedia.org/).

According to the FAO statistics, Guinea and Sierra Leone are the major rice producing countries in the region, with harvested areas that amount to hundreds of thousands of hectares (figure 4.2, panel A). The total area of rice harvested in the countries in this region has declined over the study period 1980-2000. This is mainly due to a decline in Sierra Leone during the last decade. In Guinea there was a strong but temporary decline in area harvested during the period 1983-1989. The total area of rice in Senegal is currently in the order of 85,000 hectares, and has gone up a little as compared to the 1990s. For Guinea Bissau the estimates of harvested area of rice are fluctuating around 65,000 ha over the past decade but the area was considerably larger in the early eighties, with a maximum recorded value of 143,000 ha in 1982. In the Gambia the harvested area of rice fluctuated around 14,000 ha in the past decade. In the early eighties there were a few years with lower values, but during the seventies the harvested area had been over 20,000 ha. Per hectare, the yield has increased considerably in Senegal, Guinea-Bissau and Guinea since 1980, but it diminished in Sierra Leone (FAO stat, data not shown). For the overall total production all this implied a strong increase in Senegal and Guinea, and a substantial decline in Sierra Leone (panel B, fig 4.2). Production of rice for the region currently varies between 1,100 and 2,900 kg.ha-1 (FAOSTAT data, 2006, last accessed May 2006).

Table 4.3 allows us to evaluate the relative contribution of mangrove swamp rice and other lowland rice ecologies, relative to the total area under rice cultivation. In West Africa as a whole, most of the rice stems from rain-fed cultures. Mangrove swamp rice covers only 4% of the total rice cultivation area of West Africa, however, in our study area the area of mangrove swamp rice is considerable, especially in Guinea-Bissau and Guinea (Anonymous 2000). In Gambia and Senegal a large proportion of rice cultivated area has a rain-fed lowland ecology. The irrigated lowland cultivation in Senegal is found outside our study area, in the Senegal valley.

| Country | Lowland and Mangrove-swamp rice early 90's (1000 ha) | Total Area of rice (1000 ha) | Mangrove swamp | Rain-fed lowland | Irrigated lowland | Rain-fed upland | Deep-water floating | Year of reference |
|---|---|---|---|---|---|---|---|---|
| Senegal | 75 | 75 | 8% | 47% | 45% | 0% | 0% | 91/93 |
| Gambia | 16 | 19 | 14% | 64% | 7% | 16% | 0% | 88 |
| Guinea-Bissau | 46 | 65 | 49% | 22% | 0% | 29% | 0% | 94 |
| Guinea | 157 | 364 | 13% | 25% | 5% | 47% | 10% | 91 |
| Sierra Leone | 114 | 356 | 3% | 29% | 0% | 69% | 0% | 91/94 |
| Total West Africa | | 4011 | 4% | 31% | 12% | 44% | 9% | |

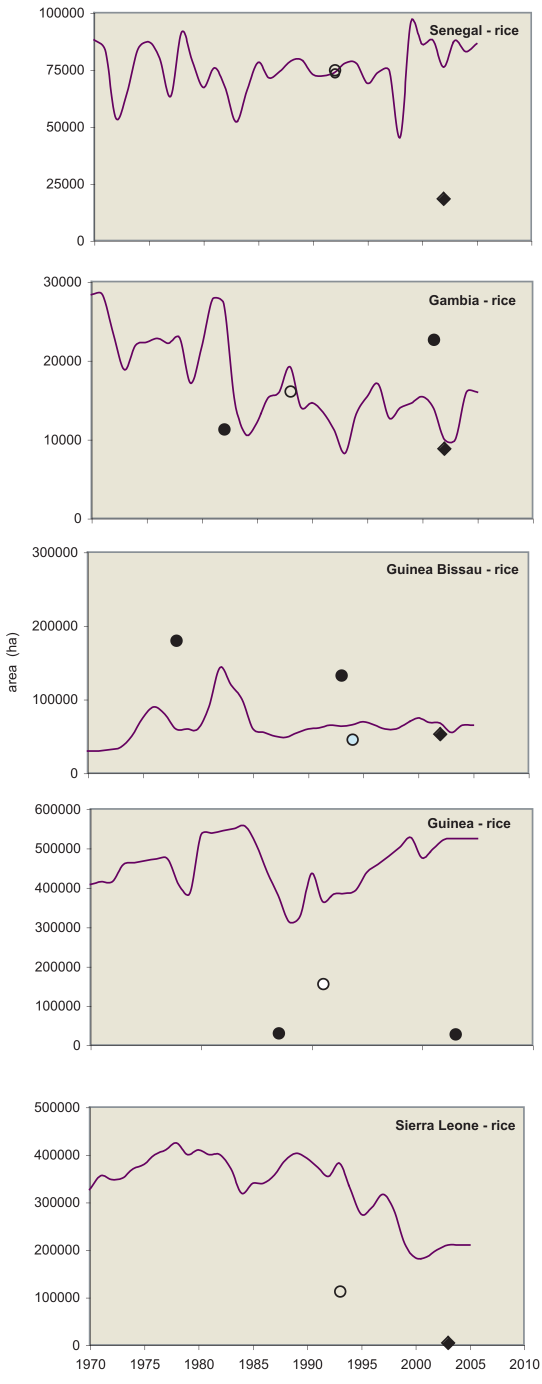
**Table 4.3. Rice cultivation in the entire countries of the Rice & Mangrove Ecoregion, the ratio between different rice ecologies (Source: FAO and West African National Agricultural Research System, in (Anonymous 2000). In the second column the cultivated area of Lowland and Mangrove-swamp rice in the early 1990s is given, calculated from the data in the remainder of the table.**

## Estimates from landcover maps

In figure 4.3 we summarise the estimates of area under lowland and mangrove swamp rice as derived from land cover maps, for the early 80s and early 2000. The maps themselves are presented in map 4.1 and Appendix 4. For comparison we also present the values for the early 1990s for area under lowland and mangrove swamp rice that had been calculated from WARDA & FAO statistics (table 4.3) as well as the country estimates for harvested area of paddy rice, irrespective of the rice ecology. Note however that the latter estimates have a greater geographical extent, especially for Senegal, Guinea and Sierra Leone. No data from land cover maps is available for Senegal and Sierra Leone in the early 1980s.

For Senegal, the area of lowland and mangrove swamp rice (south of 14º30 N and below 30 meters altitude) is estimated at 18,000 hectares (figure 4.3). The user accuracy for this estimate is 55% (see appendix 2). Any reference data is missing. The map by Stancioff *et al.* (1986), that had been used for estimating mangroves in the previous paragraph, is not suitable for estimating area of rice. This is because it does not include rice as a legend unit. All other data available has a much greater geographical extent. The majority of rice in Senegal is produced in the Senegal valley, outside our study area. Thus, we cannot make inferences about quantitative trends in our study area.

For the Gambia, the recent estimates of lowland and mangrove swamp rice vary between 23,000 ha (JICA 2001) and 8,800 ha (this study, see figure 4.3). An unpublished map for 1982 estimates the area of rice at 11,000 ha (Tyldum 2006). The FAO estimates fluctuate around 14,000 hectares since 1982, without a clear trend. Given this wide scatter in the available estimates from existing maps, and the unknown accuracy of most of the sources, we cannot distinguish subtle trends. We can however conclude that a clear trend in area under rice cultivation over the past 20 years is absent for the Gambia. For Guinea Bissau, we estimate that an area of 53,000 hectares was under rice cultivation in 2003 (figure 4.3). Both the user and the producer accuracy for this estimate are 61% (see appendix 2). The previous estimates by SCET (1978) and Cuq *et al.* (1996) were much higher, with 181,000 ha and 133,000 ha respectively. They considerably exceed the countrywide estimates by the FAO (figure 4.3).

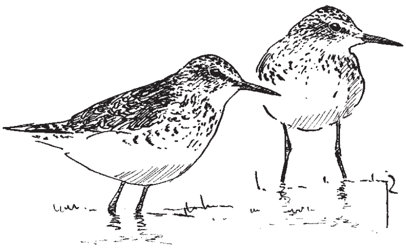



For this reason we tend to believe that they should both be considered overestimates. A large proportion of rice in Guinea Bissau has a lowland ecology (see table 4.3), and therefore we suggest that the trend can best be read from the FAO data: a peak in the area harvested in the early 1980s, a slight increase towards the mid 1990s but an absence of any clear trend since then.

The surface area of lowland and mangrove swamp rice for Guinea in our study area was estimated at 29,000 hectares in 2003 (figure 4.3), albeit with a low accuracy. The user accuracy of the estimate is 44% and the producer accuracy is 18%. A lot of pixels that were observed to be rice in the field, have in fact been classified as upland. For this reason the value should be regarded as an underestimate of the real surface area. Another relevant estimate has been derived from mapping produced in the middle of the 1980s (CCE 1990). The potential area of rice was 78,000 ha, but only 31,000 ha was productive at the time (Altenburg 1987).

Furthermore, Altenburg (1987) mentions an esti-

**Figure 4.3 The surface area of rice fields per country in the lowlands of the Rice and Mangrove Ecoregion as derived from landcover maps. Estimates refer to the area south of 14º30' N and north of 7º30' N and soil level below 30m altitude. The black dots are data derived from the landcover maps presented in appendix 4, the diamonds refer to the maps produced in this study. Open dots refer to country estimates for the early 1990s, for area under lowland and mangrove swamp rice, that have been calculated from WARDA & FAO statistics (table 4.3, Anonymous 2000). Purple lines refer to the country estimates for harvested area of paddy rice, irrespective of the rice ecology, which also have been presented in figure 4.2. Note that the open dots and purple lines refer to areas with a greater geographical extent, especially for Senegal and Guinea. Also, note the different scales of the y-axes for the different panels.**



mate of 61,000 ha of rice in the study area before 1960, but this is an unreliable estimate, based upon an old IGN topographical map. In 1991, in the country as a whole, there were 47,000 ha of mangrove swamp rice and another 110,000 ha of rain-fed lowland and lowland irrigated rice, totalling 157,000 ha in Guinea (table 4.3). Together, these data are insufficient to disclose any subtle trends. In our opinion there are neither any indications for large-scale decline nor increase in lowland and mangrove swamp rice in the study area.

In Sierra Leone the area of mangrove swamp rice was estimated at 4,000 ha in 2003 (figure 4.3), with unknown accuracy. This refers to the area north of 7º30' N and below 30m altitude. For the country as a whole, the area of mangrove swamp rice was estimated at 11,000 ha, together with another 103,000 ha of rain-fed lowland rice, totalling 114,000 ha in 1991/94 (table 4.3). Given the lack of suitable data, it is not possible to make inferences about quantitative trends in our study area.

### Summarising

Summarising the information for all of the countries in the ecoregion, there is a lack of accurate data for observing subtle changes in the study area. For Sierra Leone and Senegal we are unsuccessful in assessing developments in the area of rice in the zone of study. For the Gambia, Guinea Bissau and Guinea we feel sufficiently confident to state that there are no obvious signs of a large-scale trend in area under rice cultivation in the lowlands studied.

## 4.4 Importance for wetland-related birds

The Rice and Mangrove Ecoregion is home to many species of birds, be it Palaearctic or Afro-Tropical. Using the data on bird population densities collected in this study we will describe the composition of the bird communities for the different habitats. We will elaborate upon factors that are associated with bird density for different groups of species, and finally we shall combine them with our estimates for the available areas of rice, natural vegetation in the lowlands and mangrove that have been assessed using remote sensing (see paragraph 4.3). Note that we reserved a space in the 'method' section regarding the focus of our study. When we talk about the importance for birds we rely on density counts in a few specific habitats and a selection of bird species.

### Frequency per major class of habitat

One of the measures that are useful to evaluate the composition of the bird community in a given habitat is the frequency of observation. Estimates of density, measured in small plots, will be sensitive to chance if the estimate is based on a limited number of encounters. For that reason we present the encounter frequency of wetland-related birds in the main habitats distinguished in figure 4.4. In this figure, data for 34 species are presented. We present the selection of species that were encountered in the rice fields in more than 0.5% of the cases. In appendix 5 the complete list of wetland-related species that were encountered more than just incidentally in our plots is given.

The presence of bird species is clearly linked to habitat. Within rice-fields Yellow Wagtail, Zitting Cisticola, Squacco Heron, Spur-winged Lapwing, Cattle Egret, Wood Sandpiper, and Common Sandpiper were encountered regularly, i.e. in more than 5% of the cases (see figure 4.4). The 'natural vegetation in rice areas' habitat is characterised by the

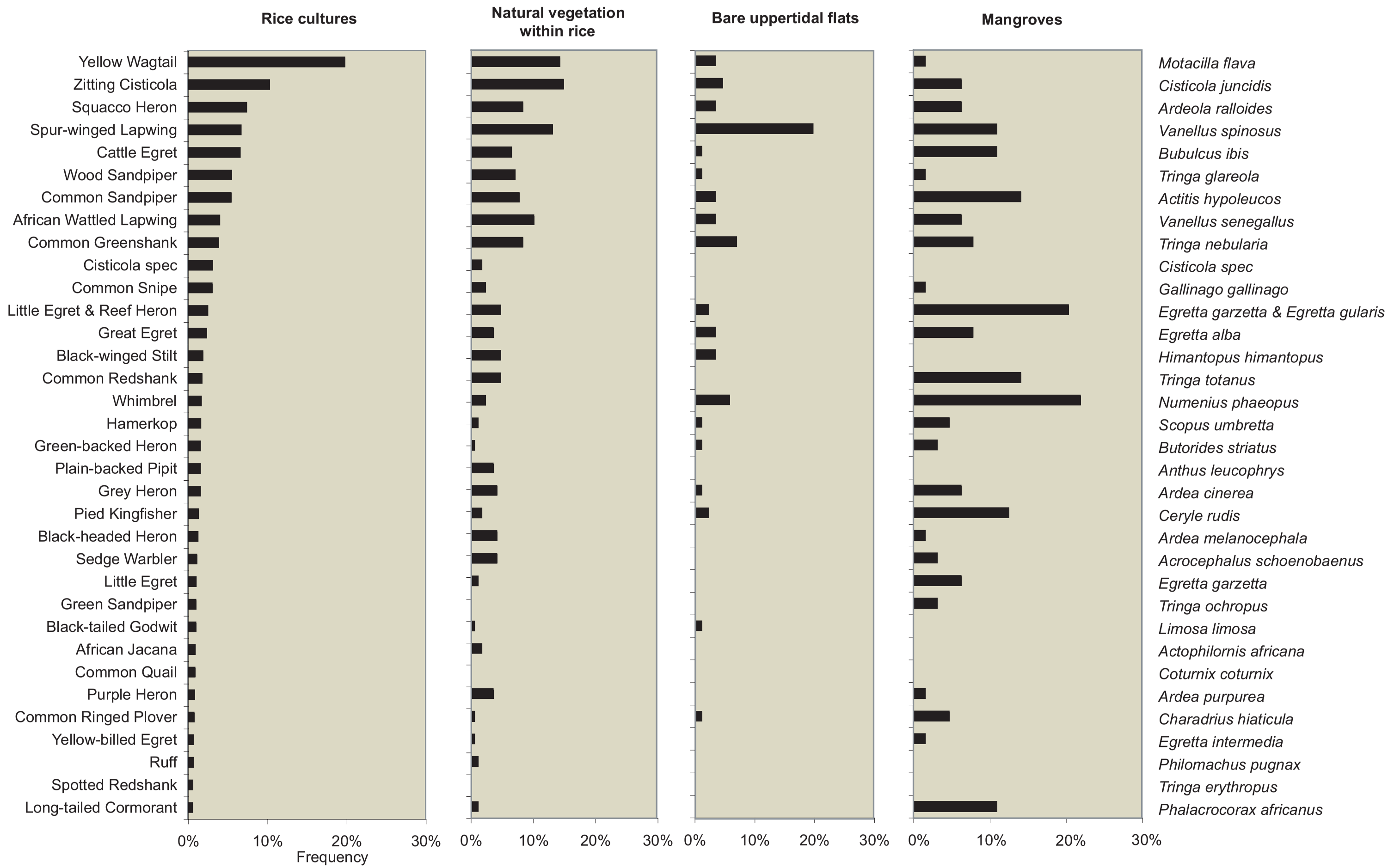
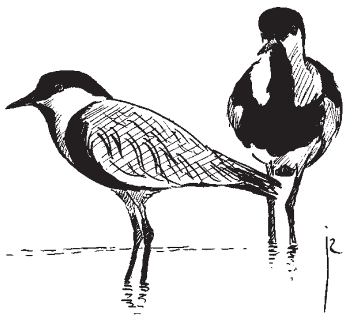



**Figure 4.4 The encounter frequency of wetland-related birds in the main habitats distinguished. The sample size is large in the rice fields (n=2679) and 'natural vegetation in rice areas' (n=168), but somewhat lower in bare upper tidal flats (n=85) and mangroves (n=64). Only species that are encountered in the rice fields in more than 0.5% of the cases are presented.**



same bird species as the rice-fields. However, the frequencies are higher. Also, there are more species that are encountered relatively often, e.g. African Wattled Lapwing, Common Greenshank, and Common Sandpiper. This can be understood from the fact that 'natural vegetation in rice areas' refers to all vegetation in the lowlands that is not forest or rice. Since it includes aquatic vegetation, vegetated upper tidal flats, and rice fields that have been fallow for one or more years, it is a diverse group of habitats. A greater diversity in habitats translates into a higher diversity of bird species.

Bare upper tidal areas are associated with species such as Spur-winged Lapwing, Common Greenshank and Whimbrel.

Finally, the mangroves have a long list of species that are frequently encountered. Whimbrel, Little Egret & Western Reef Egret, Common Redshank, Common Sandpiper, Pied Kingfisher, Long-tailed Cormorant, Cattle Egret, and Spur-winged Lapwing were encountered in more than 10% of the cases. No doubt, there is a substantial 'edge-effect' here. The diversity and the frequencies are so high because the sample of mangrove plots is biased towards edges of mangrove areas and accessible mangrove stands.

## Factors that affect bird density

For the species that have been encountered frequently, or that show a fairly uniform distribution, we can calculate bird densities in a reliable manner. For a few representative species, we illustrate the variation in relation to vegetation and water within the rice-fields (figure 4.5). Yellow Wagtail, for example, varies mostly in relation to water depth (see figure 4.5 A). The highest densities are found in fields with intermediate to high water levels. The Cisticola species are found in higher densities in the plots with greater vegetation height (figure 4.5 B). On top of that, their densities are also positively related to vegetation density and negatively to inundation percentage. These two species are small insect-eating birds.

The Cattle Egret, a large insect-eater, is especially found in areas with low vegetation (see figure 4.5 C). The Spur-winged Lapwing and the African Wattled Lapwing show the same pattern (data not shown) of selecting open areas. This pattern is opposite to that of the Cisticolas. Finally, the Wood Sandpiper is presented as an example of a small wader (figure 4.5 D). Its densities are highest at the interface of water and land, and inundation percentage is the parameter with which it is most directly correlated. The distribution of the other waders is similar.

Please note that the environmental parameters measured in the study were inter-correlated. Vegetation density correlates positively to vegetation height (Pearson r = 0.55). Areas that are inundated tend to have a greater vegetation height but lower vegetation density. On the other hand we find that the representation of each of the classes for the different

parameters is not balanced between the countries. So, the factors are confounded to some extent. This is to be expected in a descriptive study and it is a relevant warning to keep in mind when the data are used in the future.

## Numerical importance of the region for bird populations

The densities for wetland-related species that have been encountered frequently in our plots are given in table 4.4, for the major classes of habitat. Given the available area of rice habitat we have made an extrapolation of the densities into numbers present in the rice fields in the ecoregion. For many species, the variation in the estimates, expressed as a 95% confidence interval, is high. There are several reasons for this. Firstly we use average densities in rice habitat, whereas we have seen in the previous paragraph that considerable variation is present within the rice, due to variation in vegetation height, vegetation density and water availability. We cannot be more specific however, since the habitat map does not provide us details for these parameters. Secondly, our census method is not suited for species with a patchy distribution. Some of them do, nonetheless, show up in some of our plots. The Collared Pratincole, for example, which is most often observed flying in dense flocks, and which has a very clumped distribution, has been recorded on 6 occasions in rice fields. Observations of other birds, such as Black-Crowned Crane, are also rare and thus their estimates are more prone to chance effects than for birds that are encountered frequently. For species with an observed density below 50 birds per 1,000 ha, or with a lower 95% confidence limit (C.L.) that is below zero, we do not present the extrapolated value. For the other species that have been encountered frequently in the rice habitat we shall proceed to discuss the ecoregional estimates and the distribution, despite the aforementioned causes of error and variation.

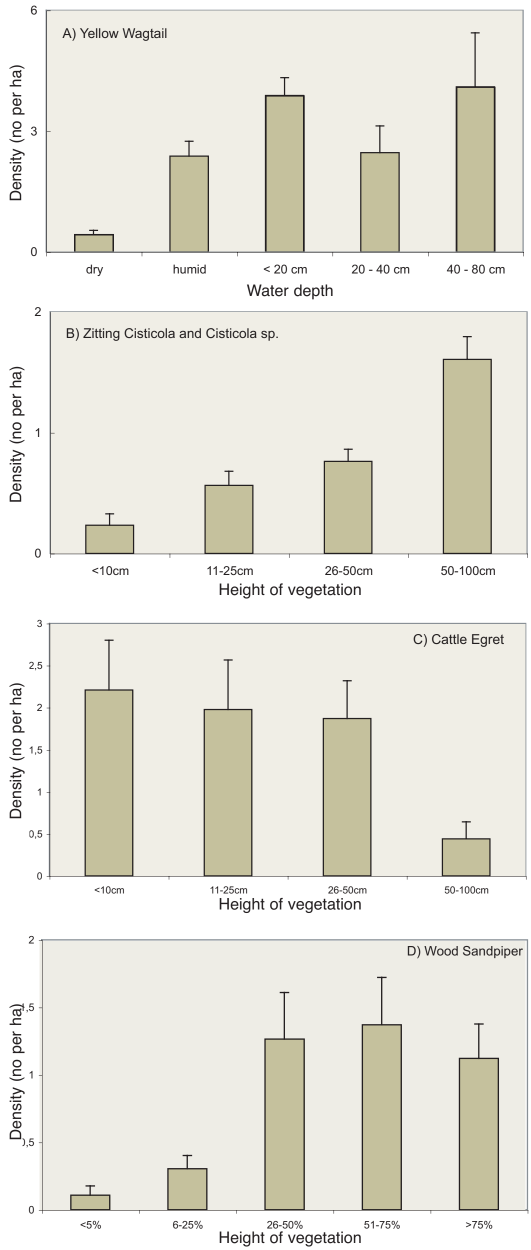



**Figure 4.5. The density of four representative species occurring in the rice fields, in relation to the most relevant factor measured for each species.**

The number of observations in mangroves, natural vegetation and upper tidal flats is considered too limited to make extrapolations. With such a limited number of observations, any extrapolation is very sensitive to chance effects. According to table 4.4, for example, there are many Wood Sandpiper in the Mangroves. This should not be considered as definitive since it is based upon two observations only and since we know that Wood Sandpiper are associated with fresh water.

*Waders*

The following waders occur frequently and are abundant in rice fields: African Wattled Lapwing is estimated to number 44,000 ± 19,000 C.L.[1] birds in the rice fields, although its distribution is more closely associated with the mangroves (table 4.4). Delaney & Scott (2002) estimate the relevant sub-population at 60,000 individuals at most, so our value may be an overestimate. Spur-winged Lapwing have high densities. They have mainly been found in open areas in each of the habitats distinguished, where they feed and nest. Their numbers in the rice fields are estimated at 61,000 as compared to a maximum population size of 700,000 in West Africa according to Delaney & Scott. Whimbrel and Common Redshank have highest densities in our mangrove plots. These species forage in the mudflats at low tide. Their numbers in the rice fields of the ecoregion may nonetheless amount to some 6-7,000. The numbers of Common Greenshank, Common Sandpiper often observed near creeks with salt water in mangrove plots, are estimated at near 30,000 each. Wood Sandpiper and Common Snipe are found in fresh water areas, and occur in the rice fields of the region with several tens of thousands of individuals. For the latter four species these numbers represent just a few percent of the total estimated for the relevant populations (Delany & Scott 2002).

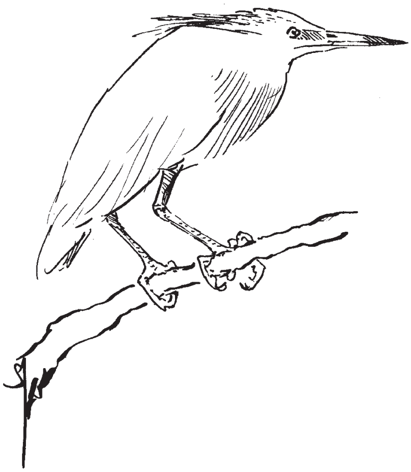
*Herons & Egrets*

Cattle Egret is estimated to be the most abundant member of this group. Over 150,000 birds are estimated for the rice fields in the region. They have been observed resting in each of the habitats, but mainly so in the mangrove vegetation. They feed in dry places with low vegetation in rice fields and natural vegetation within rice areas. Delaney & Scott (2002) estimate the maximum number of the entire sub-population of Cattle Egret at 150,000 individuals. This discrepancy might be related to our potential bias towards drier plots, but it is also possible that Delaney & Scott underestimate the number. The Squacco Heron is also estimated to occur frequently. In contrast to the low population number of 5,600 mentioned in Delaney & Scott (2002), we have seen them often in each of the habitats, except for the bare upper tidal. We estimate their number in the rice fields at 71,000 birds. Little Egret & Western Reef Egret, grouped because of potential confusion during identification, may together number 28,000 birds in the rice. They were, however, mostly seen in the mangrove plots, feeding or resting in shallow water.

*Other wetland- related species*

Yellow Wagtail is the most abundant bird species. They were predominantly found in the fresh water habitats with rice or natural vegetation and standing water. Their numbers are estimated at a staggering quarter of a million for the rice cultures in the region. This is not a strange figure, with a European population of more than 7 million birds (BirdLife International 2004). The confidence interval for the estimate is acceptable, due to the fact that we have carried out many observations for this species.

1 To facilitate reading, we will not continue to mention the confidence intervals explicitly in the text, for each extrapolated value that we present.



Individuals of Cisticola were also abundant. On several occasions Cisticolas have been observed with young. The Sedge Warbler was also frequently observed in mangroves and natural vegetation. Locally the species reaches very high densities, for example in stands of natural vegetation with *Typha sp.*, *Cyperus sp*. or *Phragmites sp*. A few very high counts in such stands bias our sample for the natural vegetation. In the rice fields we estimate their number at 9,000 birds ± 4,900 C.L.

## Habitat choice of an individual species, the Black-tailed Godwit

To conclude this section, we look at the data from the perspective of an individual species that currently attracts considerable conservation interest, the Black-tailed Godwit. The Black-tailed Godwit was encountered only infrequently in the plots (figure 4.4). Most observations were made in rice habitat (26 times), compared with a single observation on bare flats and natural vegetation within the rice area each. The average density in the rice was 0.77 Black-tailed Godwits.$ha^{-1}$ ± 0.4 s.e. (n = 2657), densities in the other habitats were negligible (table 4.4). The extrapolated value for the numbers of Black-tailed Godwits in rice fields in the ecoregion adds up to 87,000 individuals ± 97,000 C.L. Including natural vegetation (206,000 ha) and bare upper tidal flats (53,000 ha) the entire region harbours 101,000 ± 100,000 C.L. individuals. This is a realistic estimate in comparison with the estimates for the European population (> 99,000 pairs (BirdLife International 2004)), and with the 183,000 individuals estimated for the East-Atlantic Flyway population (Delany & Scott 2002). However, because the confidence intervals are so high, the estimate is not very robust. Black-tailed Godwits were found in humid fields, with vegetation of > 25 cm high (but < 25% cover). In a forward linear regression, the percentage inundation and water depth were selected as the variables best explaining variation. This model was significant, but poor ($r^2$ = 0.003).

**Table 4.4 The mean density of wetland-related birds (n/1000ha) in the main habitats distinguished. Sample sizes are given in the heading of figure 4.4. The last columns present the extrapolated values (and associated 95% confidence interval) for the rice fields in the entire region, obtained by multiplying the average density by our estimates of area for rice 112,000 ha). For species with an observed density below 50 birds per 1000 ha, or with a lower than 95% confidence interval that is below zero, we do not present the extrapolated value in the table.**

| Habitat<br>species | Rice<br>Mean | s.e. | Natural vegetation in rice areas<br>Mean | s.e. | Bare upper<br>Mean | s.e. | Mangroves tidal flats<br>Mean | s.e. | Extrapolation Rice<br>Numbers | 95% confidence interval (±) |
|---|---|---|---|---|---|---|---|---|---|---|
| Waders | | | | | | | | | | |
| African Wattled Lapwing | 391 | *86* | 1020 | *347* | 173 | *105* | 1932 | *1661* | 44000 | 19000 |
| Avocet | 10 | *7* | 0 | | 0 | | 0 | | | |
| Black-tailed Godwit | 770 | *440* | 48 | *48* | 16 | *16* | 0 | | | |
| Black-winged Stilt | 134 | *30* | 254 | *133* | 472 | *421* | 0 | | 15000 | 7000 |
| Collared Pratincole | 16 | *7* | 0 | | 0 | | 0 | | | |
| Common Greenshank | 240 | *48* | 347 | *180* | 472 | *226* | 235 | *116* | 27000 | 11000 |
| Common Ringed Plover | 44 | *14* | 42 | *42* | 104 | *104* | 50 | *30* | | |
| Common Sandpiper | 285 | *31* | 203 | *67* | 121 | *74* | 555 | *211* | 32000 | 7000 |
| Common Snipe | 201 | *32* | 44 | *24* | 0 | | 104 | *104* | 23000 | 7000 |
| Curlew Sandpiper | 11 | *10* | 0 | | 191 | *175* | 87 | *75* | | |
| Green Sandpiper | 58 | *19* | 0 | | 0 | | 152 | *139* | 6600 | 4100 |
| Little Ringed Plover | 14 | *11* | 19 | *14* | 0 | | 0 | | | |
| Little Stint | 9 | *5* | 0 | *0* | 99 | *99* | 0 | | | |
| Marsh Sandpiper | 13 | *9* | 4 | *4* | 74 | *74* | 0 | | | |
| Painted Snipe | 14 | *7* | 0 | *0* | 0 | | 0 | | | |
| Common Redshank | 67 | *14* | 78 | *29* | 0 | | 444 | *175* | 7500 | 3100 |
| Ruff | 187 | *78* | 40 | *29* | 0 | | 0 | | 21000 | 17000 |
| Senegal Thick-knee | 14 | *5* | 0 | | 0 | | 1158 | *679* | | |
| Spotted Redshank | 83 | *39* | 0 | | 0 | | 0 | | 9300 | 8500 |
| Spur-winged Lapwing | 542 | *62* | 840 | *237* | 1080 | *341* | 410 | *179* | 61000 | 14000 |
| Temminck´s Stint | 5 | *3* | 0 | | 0 | *0* | 0 | *0* | | |
| Whimbrel | 56 | *13* | 34 | *23* | 311 | *197* | 1246 | *491* | 6300 | 2800 |
| White-headed Lapwing | 38 | *26* | 0 | | 0 | | 0 | | | |
| Wood Sandpiper | 487 | *69* | 399 | *144* | 67 | *67* | 215 | *162* | 55000 | 15000 |
| Ibis, Hammerkop | | | | | | | | | | |
| Glossy Ibis | 4 | *3* | 502 | *502* | 0 | | 0 | | | |
| Hammerkop | 86 | *19* | 42 | *32* | 54 | *54* | 120 | *86* | 10000 | 4000 |
| Herons and egrets | | | | | | | | | | |
| Black Heron | 208 | *137* | 0 | | 74 | *74* | 0 | *0* | | |
| Black-headed Heron | 48 | *14* | 198 | *113* | 0 | | 10 | *10* | 5400 | 3000 |
| Cattle Egret | 1405 | *217* | 1106 | *483* | 24 | *24* | 1438 | *737* | 159000 | 48000 |
| Great Egret | 135 | *26* | 630 | *591* | 73 | *57* | 453 | *291* | 15000 | 6000 |
| Green-backed Heron | 198 | *120* | 5 | *5* | 74 | *74* | 556 | *494* | | |
| Grey Heron | 128 | *52* | 106 | *48* | 43 | *43* | 191 | *106* | 14000 | 12000 |
| Little Egret | 73 | *28* | 7 | *5* | 0 | | 383 | *229* | 8200 | 6100 |
| Little Western Reef Egret | 248 | *66* | 77 | *42* | 56 | *39* | 1510 | *707* | 28000 | 15000 |
| Purple Heron | 38 | *11* | 84 | *42* | 0 | | 17 | *17* | | |
| Squacco Heron | 626 | *97* | 462 | *178* | 62 | *36* | 306 | *199* | 71000 | 21000 |
| Yellow-billed Egret | 21 | *6* | 2 | *2* | 0 | | 40 | *40* | | |
| Other wetland related birds | | | | | | | | | | |
| Plain-backed Pipit | 87 | *18* | 73 | *36* | 0 | | 0 | | 10000 | 4000 |
| Bluethroat | 9 | *5* | 0 | *0* | 0 | | 0 | | | |
| Cisticola spec | 170 | *26* | 101 | *61* | 0 | | 0 | | 19000 | 6000 |
| Common Quail | 38 | *9* | 0 | | 0 | | 0 | | | |
| Crested Lark | 30 | *10* | 8 | *8* | 32 | *32* | 0 | | | |
| Great reed Warbler | 0 | | 35 | *35* | 0 | | 104 | *104* | | |
| Long-billed Pipit | 8 | *8* | 0 | | 0 | | 0 | | | |
| Malachite Kingfisher | 13 | *10* | 5 | *5* | 0 | | 0 | | | |
| Pied Kingfisher | 74 | *18* | 44 | *31* | 68 | *56* | 784 | *419* | 8400 | 4000 |
| Red-throated Pipit | 9 | *6* | 0 | | 0 | | 0 | | | |
| Reed warbler | 21 | *12* | 0 | | 0 | | 0 | | | |
| Savi´s Warbler | 5 | *3* | 61 | *61* | 0 | | 0 | | | |
| Sedge Warbler | 81 | *22* | 4787 | *3277* | 0 | | 269 | *186* | 9100 | 4900 |
| Singing Bush Lark | 6 | *4* | 0 | | 0 | | 0 | | | |
| Winchat | 40 | *18* | 0 | | 0 | | 0 | | | |
| Yellow Wagtail | 2374 | *198* | 893 | *301* | 151 | *114* | 138 | *138* | 268000 | 44000 |
| Yellow-throated Longclaw | 48 | *19* | 51 | *51* | 0 | | 0 | | 5400 | 4100 |
| Zitting Cisticola | 801 | *77* | 964 | *341* | 490 | *354* | 287 | *165* | 90000 | 17000 |
| African Jacana | 141 | *55* | 256 | *152* | 0 | | 0 | | 16000 | 12000 |
| Lesser Jacana | 5 | *3* | 0 | | 0 | | 0 | | | |
| Purple Swamphen | 0 | | 71 | *71* | 0 | | 0 | | | |
| Long-tailed Cormorant | 23 | *8* | 20 | *19* | 0 | | 747 | *323* | | |
| Black Crowned Crane | 28 | *20* | 151 | *151* | 0 | | 0 | | | |
| White-faced Whistling Duck | 99 | *54* | 0 | | 0 | | 0 | | | |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# 5

# Discussion

## 5.1 Current landcover maps on a regional scale

On an ecoregional scale, we have mapped the major wetland complexes in the lowlands. The maps provide a good insight into the geographical position of these habitats. The classification produced is of acceptable accuracy in the northern part of the region, Senegal to Guinea Bissau, for our purpose of estimating land cover. In the southern part, the accuracy is limited (see paragraph 4.1). Previous maps, however, and other estimates of wetland area, are generally not at all associated with measures of accuracy. The variation between individual estimates of rice and mangrove in time is large, and thus, subtle trends cannot be distinguished. The presence or absence of large-scale trends will be discussed below. The scale for which the map is made is ecoregional. It is possible that local change may not be apparent on the map, however significant the change may be at that local scale.

Future work could elaborate upon the maps produced. For example, in our classified image all bare areas, below 30 m altitude, have been grouped into one class. Bare upper tidal flats have not been distinguished as such in our classification, but grouped with bare intertidal areas. To provide a better estimate for the area of bare upper tidal flats it is possible to divide the current class of bare areas into two, using the value of reflectance in band 6 of the Landsat TM images. The value in band 6 differed significantly between intertidal and upper tidal plots in our set of training sites (T-test $F_{1,180} = 41$, $p < 0.001$). Band 6 relates to temperature, and indirectly to soil moisture. Using this information one can re-classify the 'warm' pixels that belong to the areas classified as bare (values for band 6 > 157) as 'bare upper tidal'. The 'cooler' pixels (values for band 6 < 156) that belong to the areas originally classified as bare, can then be re-classified as 'bare intertidal'. In a similar way, one can use the established relationships between the Normalised Difference Vegetation Index (NDVI, a ratio between band 3 and band 4) and the observed density of vegetation in our set of training sites. Using NDVI and Band 6 one can thus make more detailed classifications than the maps presented here,

**Rice cultivation**

**a, e) In the managed polder of Koba, tractors and other machines are used in the rice cultures (Koba, Guinea 2006). Apart from a few examples, however, the use of such machines is rare in the Rice and Mangrove Ecoregion. b) Separating the grains of rice from the rice plant. c) Rice just manually harvested lies waiting for transport away from the fields (Wassou, Guinea 2006). d) Extensive area of tidal rice, at the time of harvest. Note the young Avicennia tree (Koba, Guinea 2006). f) Sifting the rice, using the force of the wind. h) Before cultivation can start, mangroves are cleared and salts are washed from the soils for a few years (Taigbe, Guinea 2006).**

**Close-up of a full-grown rice plant**

and distinguish areas within a certain class, based upon vegetation density and soil moisture. For the purpose of extrapolating bird population densities this would be an interesting exercise.

## The extent of mangroves

Worldwide the mangroves are declining at a rapid rate, currently 1.1% per year (Wilkie & Fortuna 2003). Some of the mangrove stands in this region of West Africa nonetheless appear to have maintained their status. In Gambia, the situation is stable in terms of surface area, at least since 1993. In Guinea Bissau no large-scale trend is present. In Senegal, however, we estimate a decline of about 0.8% per year since 1985. For Guinea and Sierra Leone, the recent estimates suggest a decline, but the accuracy of these estimates is such that we can be neither quantitative nor confident. The climatic drought obviously has had a severe negative impact on the extent of the mangrove forest, especially in the north of the ecoregion where rainfall is limited and there have been observations of a severe die-off (Diop *et al.* 1997; Bertrand 1999). The area of bare upper tidal flats has increased during that time, which for the Saloum is documented by Diop *et al.* (1997). The dying off of mangroves in the Saloum, the Casamance and in the Bintang Bolon in the Gambia happened during the drought years of the 1970s and early 1980s. Now, with more suitable rainfall conditions apparently prevailing (see paragraph 2.2), there is regeneration of the mangrove, but often *Rhizophora* is replaced by *Avicennia*.

The construction of anti-salt dams in the branches of the rivers and estuaries has diminished the available area suitable for mangrove. Upstream of dams the water becomes fresh, tidal influence stops, and mangroves disappear. Downstream the water may become too salty. On top of that there may be problems locally with soil acidification. Anti-salt dams are constructed to facilitate the cultivation of rice. In fact, everywhere where intertidal areas are converted to agriculturally productive terrain, mangroves are lost. The agro-hydrological works in the region, some of which were implemented before our study period (see paragraph 2.5), have certainly affected the potential range of mangroves locally. When successful they provide valuable and productive land instead. When they are not successful, considerable areas turn into fresh or brackish marsh (natural vegetation). There was an estimated 795,000 ha of mangrove in 2002/03, relative to 112,000 ha of lowland and mangrove swamp rice present. As far as we can see, the scale on which these conversions take place is not large, relative to the total area of mangrove in the ecoregion. Besides, although mangroves turn into agricultural land, this also happens the other way around.

## The extent of rice fields in the mangrove zone

According to Duarte (2006), rice fields in Guinea Bissau are hypothesized to have diminished in extent. He presents interview data from a small sample of three villages to illustrate this. Cheap import-


**Kawsu Jammeh (middle, blue cap) with local youth returning from the rice fields. Note the particular dress of the two persons second and fifth from the left. These clothings are worn for a cultural occasion**

ed rice, soil degradation and harsh climatic conditions have apparently diminished the motivation to work in the rice-fields, according to that study. There has been a move of young people to the cities, creating a shortage of labour in the countryside to maintain the rice fields and their intricate system of dams. A large part of the work, which used to be done by the men, is now done by women and children (Duarte 2006). During our ground surveys we visited many areas in different parts of the region. It is obvious that there is a great diversity in local circumstances. In many areas rice-cultivation continues as it has done for the past decades. Similarly, one can find areas that have been abandoned for years. On a small scale new areas are brought under cultivation or return to a state of mangroves.

From the comparison of maps alone, we cannot make a reliable judgement about the changes over time in areas of lowland rice. We will here shortly summarise the available information per country. For Senegal, there is no reference data for earlier periods, so we have no clue about quantitative trends for the study area. Nationwide the production of rice is increasing (FAO-stat), but this figure is dominated by the irrigated rice from the Senegal valley. The rice cultivation in the study area has suffered substantially from the African drought. Furthermore, rice production in the lowlands of our study area is greatly hampered by salinisation and acidification. Nonetheless, the Senegalese government, local people, and international donors invest in rice production, and many anti-salt dams are being constructed. According to Cormier-Salem (1999) it should be possible to maintain productivity in areas where rice is currently cultivated, and potentially recover areas that are degraded when rainfall returns to pre-drought conditions. The available information thus suggests that the area of lowland and mangrove swamp rice will have declined during the drought years, and will currently be stable or even increasing. In the Gambia the area of rice has been fluctuating without a trend. Guinea-Bissau had a slight increase in the area of rice during the mid 1990s, but a clear trend has been absent since then. Our data for Guinea-Bissau are not in line with the suggestion by Duarte (2006) that there has been a decline. In Guinea, there are no indications of a large-scale decline or increase in rice area in the lowlands. Nationwide there has been a large decline in harvested area in the mid 1980s, followed by a period of recovery. In the field we have clearly observed that there is sufficient motivation to work in the rice fields, as long as the water management is properly arranged. Many people are prepared to travel back and forth from town to cultivate their land when this is the case. In Sierra-Leone the civil war has caused many people to migrate to neighbouring countries. Nationwide the area of rice harvested has declined, and we assume that the same happened in the lowlands.

## 5.2 Importance for wetland-related birds

The data presented in this study quantify the relative importance of the different habitats for birds in the middle of the dry season. For some species we were able to examine the role of different abiotic factors in relation to the distribution of the birds. The rice habitat harbours many species. Yellow Wagtail, Zitting Cisticola, Squacco Heron, Spur-winged Lapwing, Cattle Egret, Wood Sandpiper, and Common Sandpiper were encountered regularly. None of them appears to be restricted to the rice, but a few species, Black-tailed Godwit, Yellow Wagtail appear to have a preference for it. If only by the enormous scale over which the rice occurs (more than hundred thousand hectares), the rice in the region is of importance for a great number of birds. This has been illustrated by discussing a few extrapolations in paragraph 4.4. Within the season, depending on the stage of cultivation, the function of the rice habitat for birds changes from a place to forage for soil invertebrates, to a fishing ground, and again to a source of invertebrates, but now also with seeds and maybe more insects. As a consequence, the identity of bird species that use the fields also changes. The composition of the bird community in other habitats has also been described in this study. Each of them functions as a place for breeding, foraging, and resting for a variety of bird species. As for the rice, the importance of each of these functions changes with the seasons. There is no way to judge whether one habitat is more valuable than the other, but at least we have a tool to better describe the nature of changes of any variation in land cover.

## 5.3 Threats

Below, we will outline several threats to this eco-system. The major threats for degradation of habitats stem from climate and human exploitation. Climate is quite unpredictable. Zwarts *et al.* (in prep) show that one can equally find literature sources that predict rainfall to increase and those that predict the opposite. We will therefore not pay much attention to speculations about changes to be expected here. It is clear that if the rains do not come in sufficient amounts in the north of the region, this will have negative repercussions for the area of both mangroves and rice. If the rains are too abundant in the south, this might hamper the rice cultivation there.

Human exploitation in the ecoregion comes in many ways. The most relevant ones are (1) as (rice) agriculture, with or without some sort of water management, (2) in the form of exploitation of mangroves for fuel and wood for construction, and (3) in the form of harvesting of salt, oysters, shell

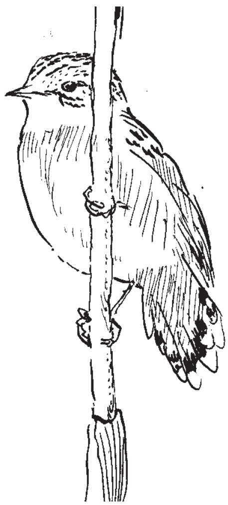
***Whimbrel near Rhizophora mangrove***

fish, fish and birds. Rice cultivation and human settlement have been an integral part of the Rice and Mangrove Ecoregion for centuries, and all of the above-mentioned activities have always taken place. There is an increasing population growth, though, and thus the scale at which these activities are undertaken increases. The threats to the system are general threats, and lie in inappropriate water management, unsustainable harvesting strategies of oysters, and unlimited extraction of wood.

Inappropriate water management poses a risk because it may lead to stagnant water on the one hand, associated with several types of disease, or excessive drainage of soils on the other hand, potentially leading to soil-acidification. Examples have been discussed in paragraph 2.5; in many places people have lost otherwise productive areas by improper management of water. Lack of awareness is a threat, but many people do know of these problems nowadays. A specific threat related to the management of water is the proposed hydro-electric power dam in the Gambia River, upstream at Sambangalou (see map 2.3(Sogreah Ingenerie 1999)). However, the implementation of this dam is guided by elaborate environmental impact assessments (EIAs, e.g. (IRD 2004)). So at least the costs and benefits have been weighed up. The other specific threats in this category are the many anti-salt dams constructed in the south of Senegal. As long as these dams are implemented carefully, and the water management is organised well, they may enhance rice-cultivation. We do not know to what extent this happens in practice. As far as we know, there is a need for studies evaluating the benefits in terms of rice production against the changes in biodiversity up- and downstream for a number of these projects.

Unsustainable harvesting of oysters refers to the cutting of the mangrove roots to which the oysters are attached, while harvesting. By cutting the roots as well as the oysters themselves, people obtain firewood for preparing the oysters. However, the available substrate for young oysters to attach themselves to diminishes and the mangroves may even die. Locally, this is still happening. There are also examples of places where people do not use this strategy or where they do not use it any more, thanks to an increased awareness of the consequences.

The unlimited extraction of wood from mangrove stands is a clear threat as well. The wood is very hard and valuable for construction. Often, wood from mangroves is the easiest available source of energy for extracting salt, smoking fish, or preparing oysters. Locally, the effect of exploiting the mangroves can be strong, as suggested by Chaume *et al*. (1993) near the city of Conakry in Guinea. National governments, and donor agencies, are aware of the limitations of this resource. Throughout the region - in upland areas though - there are examples of projects that help communities to manage community forests in order to maintain a continued supply of wood in the long term. Other efforts relate to the provision of alternative sources of energy. However, deforestation appears to be a very tough problem, and the positive examples are rare. Therefore a continued and increased effort is required.



Finally, one might think that abandonment of rice-fields is a threat to the system. If indeed economic circumstances change in such a way that people will turn to other economical activities than the cultivation of rice, there will be a decline in area under cultivation. From the point of view of national food security and independence of rice imports this is a problem. From a biological point it implies an increase of salt-water habitat (mangroves and natural vegetation) at the expense of freshwater rice habitat. It is difficult to see that this could be a problem, given the amount of available alternative freshwater habitat. Maybe for a species like the Black-tailed Godwit, that appears to forage mainly in wet rice fields, it could be an issue when more than half of the available rice cultures would dissappear. But it is difficult to imagine a change at that scale happening in the near future.

# 5.4 Synthesis

Our aim was to obtain an overview over the developments in the region and to quantify the large-scale developments. We did not find evidence of specific large-scale changes or threats during the study period, on an ecoregional scale, except for a decline in the area of mangrove in the south of Senegal during the African drought. However, the data assembled appears not to be suitable for discriminating very sharply. In addition the methodology used has not been applied for detecting local change, which may be very important on that scale.

The methods of cultivation in the mangrove swamps have not changed over the past decades. Locally there are all kinds of developments. Some are positive and some are negative. Examples are the cutting of mangroves for new rice polders, the construction of larger-scale dams to prevent salt-intrusion, the salinisation and acidification of existing fields, the recovery of degraded land, over-harvesting of wood, oysters or other resources, and the adoption of newer more sustainable harvesting strategies. The general threats identified are an inappropriate water management, unsustainable harvesting strategies of oysters, and unlimited extraction of wood.

Land use developments in these lowland areas may be guided and altered, but this requires knowledge of local conditions and appropriate water management. The latter is very delicate. One needs to take into account such factors as climate (north or south in the region), position in the estuary, soil, history and socio-economic setting. For example: anti-salt dams, or other hydrological works can be used and are used to safeguard or enhance the productivity of soils. But if the management of water is not adequate, the investment is not a success and a large area becomes degraded, although the resulting vegetation may still be valuable from a biological point of view. Generally, the up and down stream effects of the anti-salt dams in terms of biodiversity are however unknown.

In this study, an extensive, detailed, and quite consistent database has been collected on bird densities in the rice fields. Additional information on the composition of the bird community has been gathered in the lowland natural vegetation, the bare upper tidal areas and the mangroves. The wetlands in the entire lowland zone are of great importance to many species of birds, both migratory Palaearctic birds and Afro-tropical species. Unlike regions such as the Bijagos (Guinea Bissau), the Banc d' Arguin (Mauritania), and the Inner Niger Delta, where major aggregations of birds are present at certain times of the year, the birds are more spread out in this wetlands ecoregion.

The different distinguished habitats harbour overlapping bird communities. Both rice and natural vegetations have value as bird habitat. We can now quantify the relative importance of different vegetation communities and the role of different abiotic factors in relation to habitat requirements of the birds. This means that we have a tool to better describe the nature of changes of any modification in land cover. Throughout West Africa, there is a need and a desire to increase the rice production. When planned and implemented carefully, this does not necessarily have a negative impact on biodiversity in birds.

The mangrove ecosystem is an area that is used in multiple ways. Human use is an integral part of it. There is good reason to keep it as such, but lots of work needs to be done to improve the welfare of people, given the natural constraints.

## 5.5 Recommendations

A wise use of the natural resources in the ecoregion depends on more than knowledge of the biological component alone. Recommendations for sustainable management need to take into account economical and sociological issues that fall beyond the scope of this study. However, the biological information that is presented in this study does lead to the identification of a few opportunities.

We suggest giving further support to local populations in order to enhance their welfare within the constraints of their natural environment. One of the means to do so is to continue to provide local populations with the means to implement proper water management on an appropriate scale, to be managed autonomously, by themselves. This should be done only after a careful evaluation of the local conditions. It is very necessary to provide local populations with the means to implement the use of alternative sources of energy.

We recommend studying the temporal changes in wetland habitats in more detail than has been done here, for a selection of areas. For this, one should make use of information from multiple sources (CORONA, Spot, Landsat, groundtruthing and local interviews). Some of these sources have detailed images that relate to periods before the early 1980s. Such an analysis will have a greater resolution in space and time.

One should particularly focus on the study of the up and down stream effects of some of the anti-salt dams, in terms of biodiversity and economic benefits. It is recommended to collect systematically, parameters of biodiversity in the field up and down stream from dams.

We also recommend studying the effects of deforestation in mangroves near major urban areas, in terms of cover and composition.

We suggest that one should elaborate upon the data analysis presented in this study, by updating the maps created with information on tree density, vegetation cover and soil moisture. Bird densities have in this study been related to these same parameters. Together, the two sets of data can yield useful extrapolations. The accuracy of the maps for Sierra Leone and Guinea Conakry needs to be improved.

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# Appendix 1

## Landcovermaps in the lowlands of the Rice and Mangrove Ecoregion, per country, for the period 2002-03 and the early 1980s.

### < Map app 4.1.

**Land cover in the lowlands of Senegal and The Gambia in 2002 assessedusing remote sensing.**

### < Map app 4.2.

**Land cover in the lowlands of Senegal in 1985 assessed using remote sensing (Stancioff *et al.* 1986). Data courtesy of G. Tappan, USGS EROS, South Dakota, USA.**

### < Map app 4.3.

**Land cover in the lowlands of The Gambia in 1985 assessed using remote sensing (G. Tyldum unpublished).**

### < Map app 4.4.

**Land cover in the lowlands of Guinea-Bissau in 2002 assessed using remote sensing.**

### < Map app 4.5.

**Land cover in the lowlands of Guinea Bissau in 1978 assessed using remote sensing (SCET-INTER-NATIONAL 1978). Reprinted with permission from IÚBO-CNRS. Droits concedes par IÚBO-CNRS pour le compte du laboratoire Géomer (LETG UMR 6554).**

### < Map app 4.6.

**Land cover in the lowlands of Guinea-Bissau in 1993 assessed using remote sensing (source SCET International (1978) and Landsat images 1987). Reprinted with permission from IÚBO-CNRS pour le compte du laboratoire Géomer (LETG UMR 6554, Cuq *et al.* 1996).**

### < Map app 4.7.

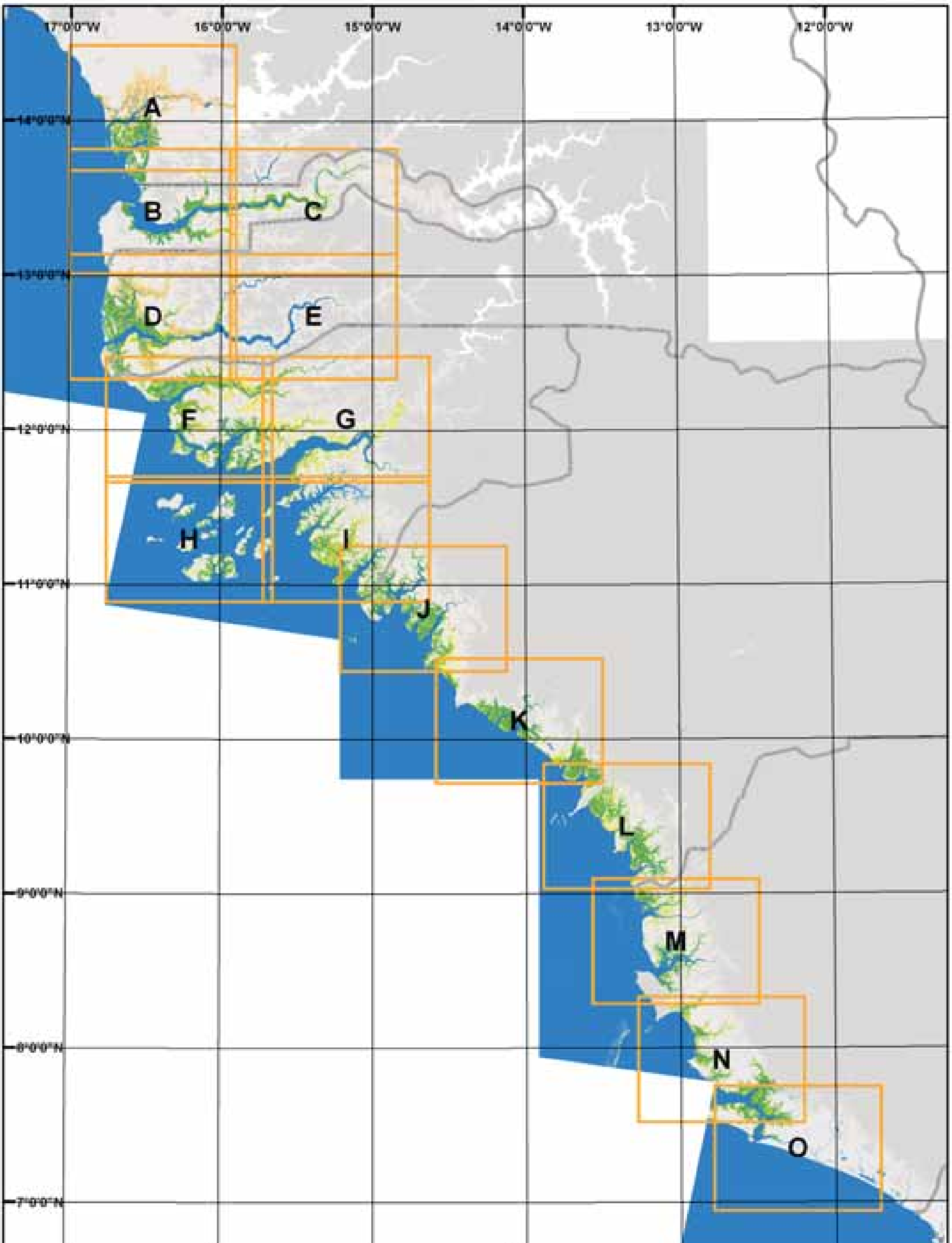
**Land cover in the lowlands of Guinea Conakry in 2003 assessed using remote sensing.**

### < Map app 4.8.

**Land cover in the lowlands of Guinea Conakry in 1987 assessed using remote sensing (CCE 1990).**

### < Map app 4.9.

**Land cover in the lowlands of Sierra Leone in 2003 assessed using remote sensing.**




Overview maps

Altenburg & Wymenga

A&W report 824
teknr. 435-037a/12012007/ld
topography: ESRI

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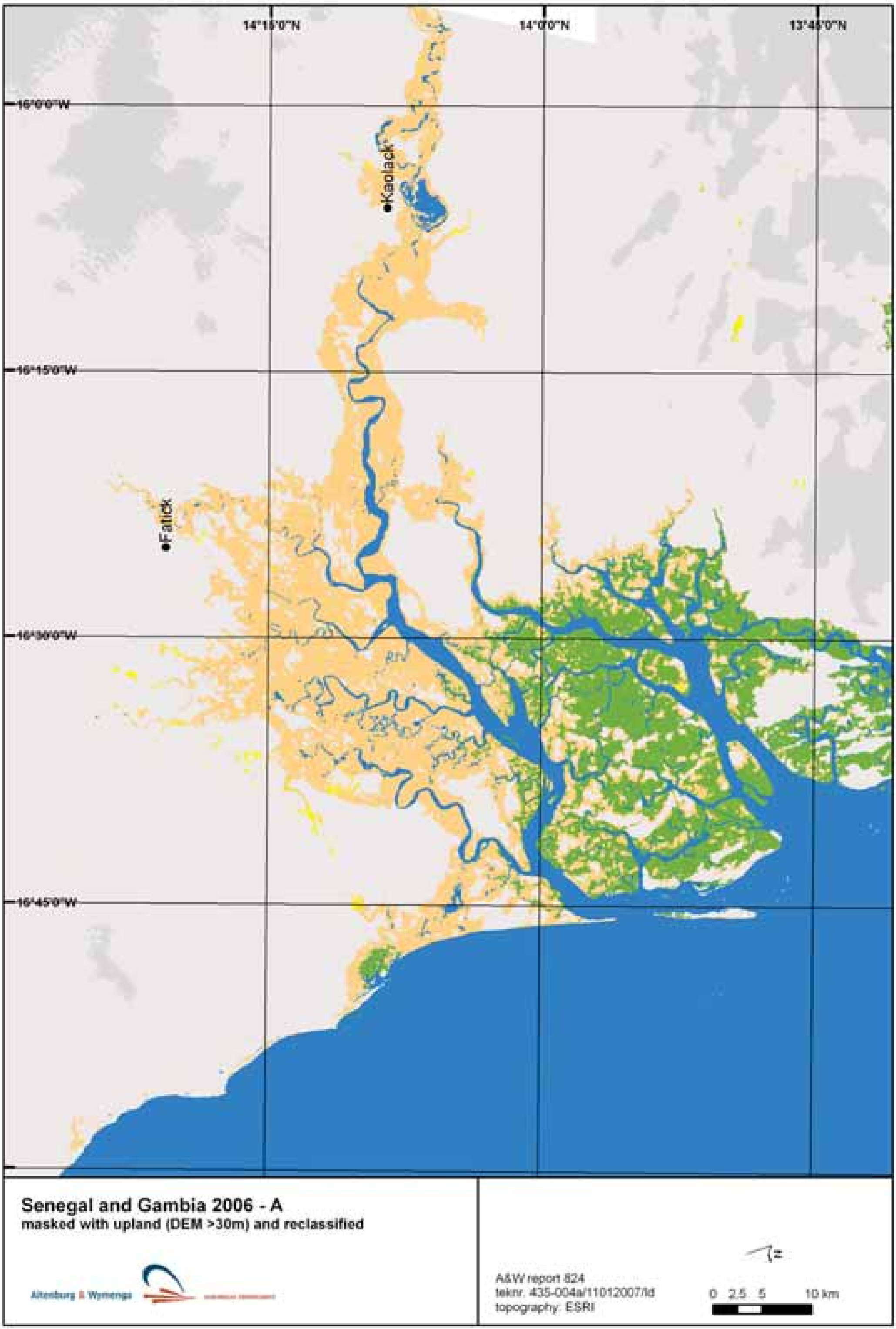
**Map app 4.1.**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14°0'0"N
13°45'0"N
16°0'0"W
16°15'0"W
16°30'0"W
16°45'0"W
Kaolack
Fatick
Senegal and Gambia 2006 - A
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
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topography: ESRI
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**Senegal and Gambia 2006 - B**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
teknr. 435-005a/11012007/ld
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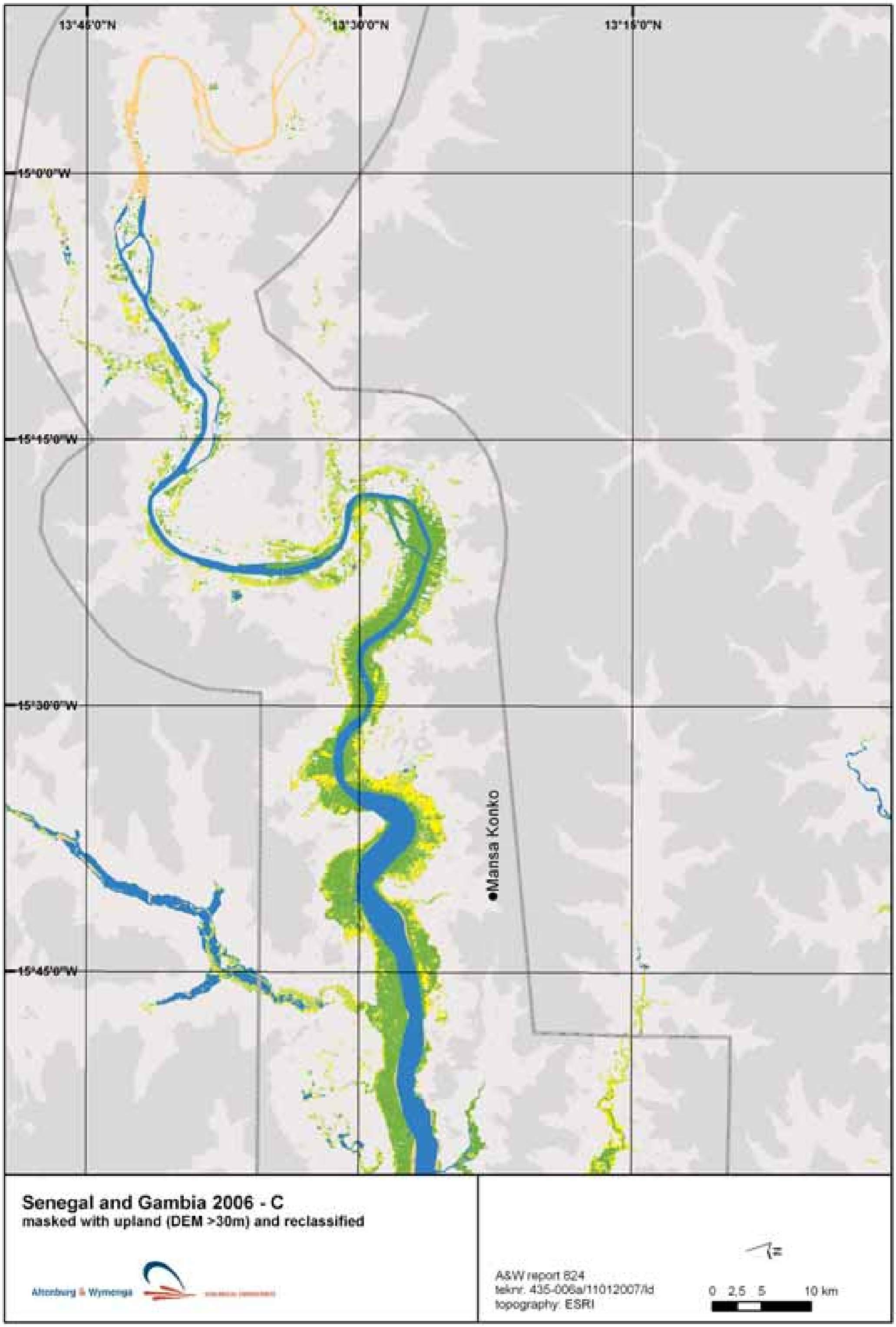
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13°30'0"N
13°15'0"N
15°0'0"W
15°15'0"W
15°30'0"W
15°45'0"W
Mansa Konko
Senegal and Gambia 2006 - C
masked with upland (DEM >30m) and reclassified
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topography: ESRI
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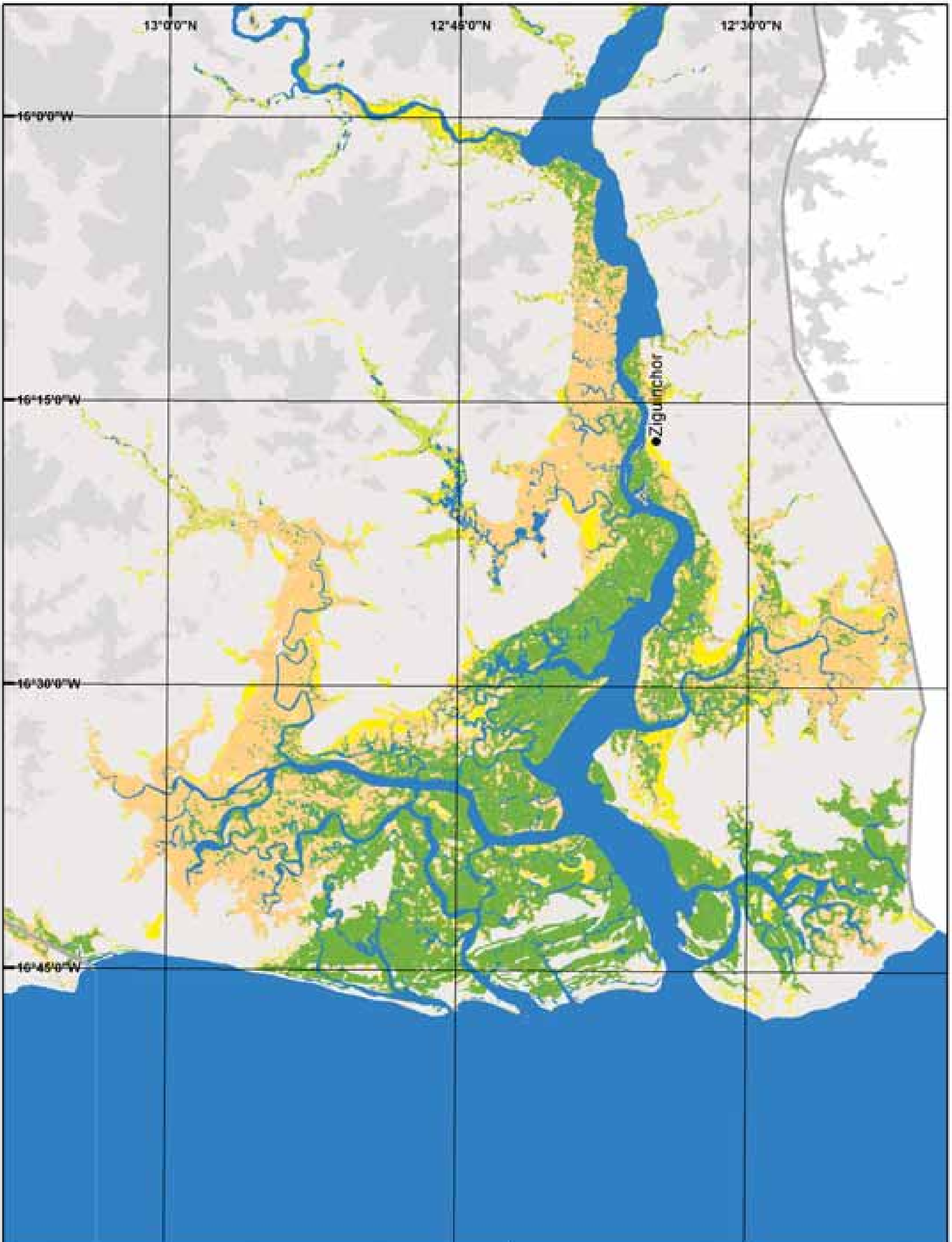


**Senegal and Gambia 2006 - D**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

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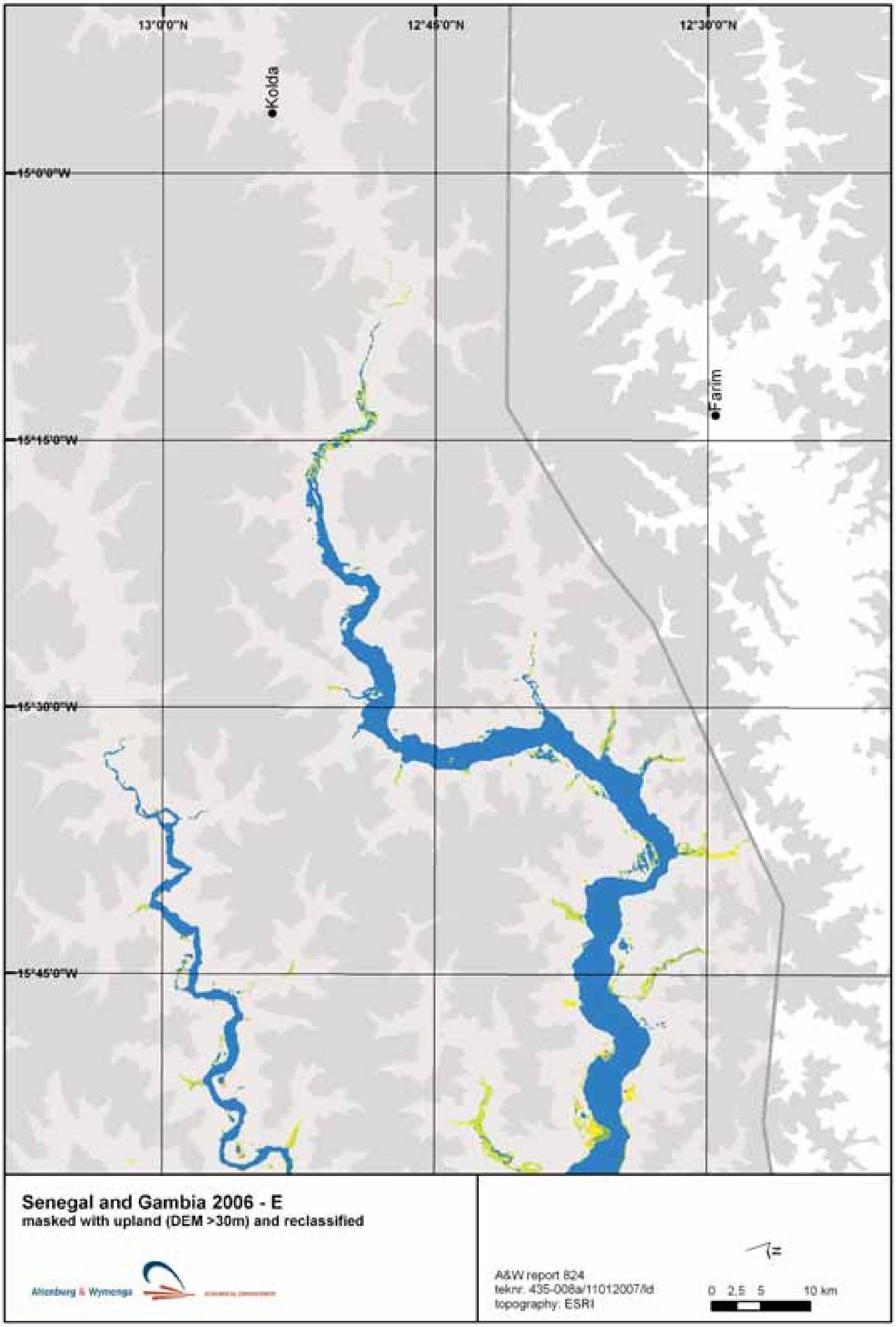
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Kolda
Farim
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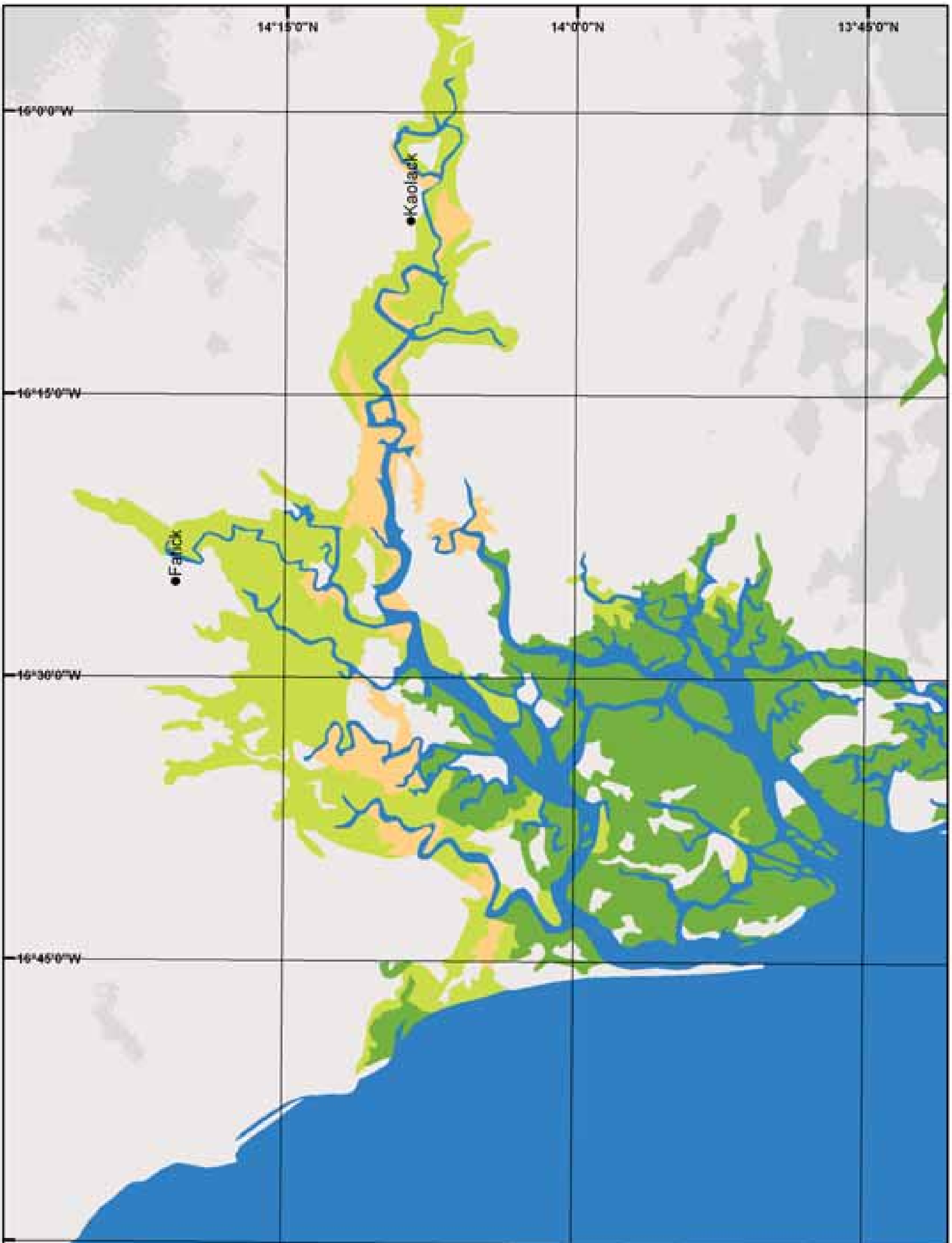
15°45'0"W
Senegal and Gambia 2006 - E
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr: 435-008a/11012007/ld
topography: ESRI
0 2.5 5 10 km

**Map app 4.2.**




**Senegal and Gambia 1985 - A**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
teknr. 435-009a/11012007/ld
topography: ESRI

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**Senegal and Gambia 1985 - B**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
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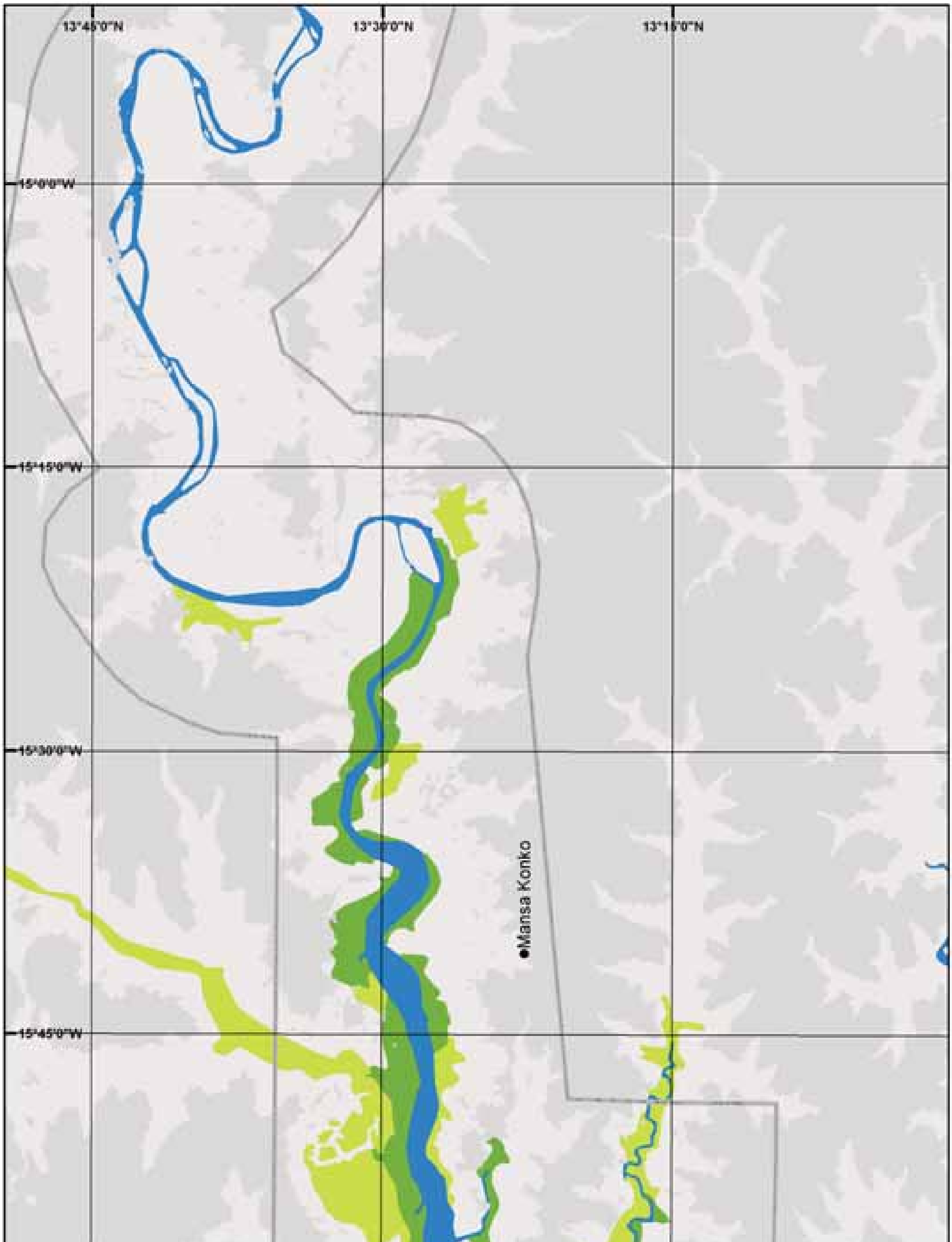


**Senegal and Gambia 1985 - C**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

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topography: ESRI

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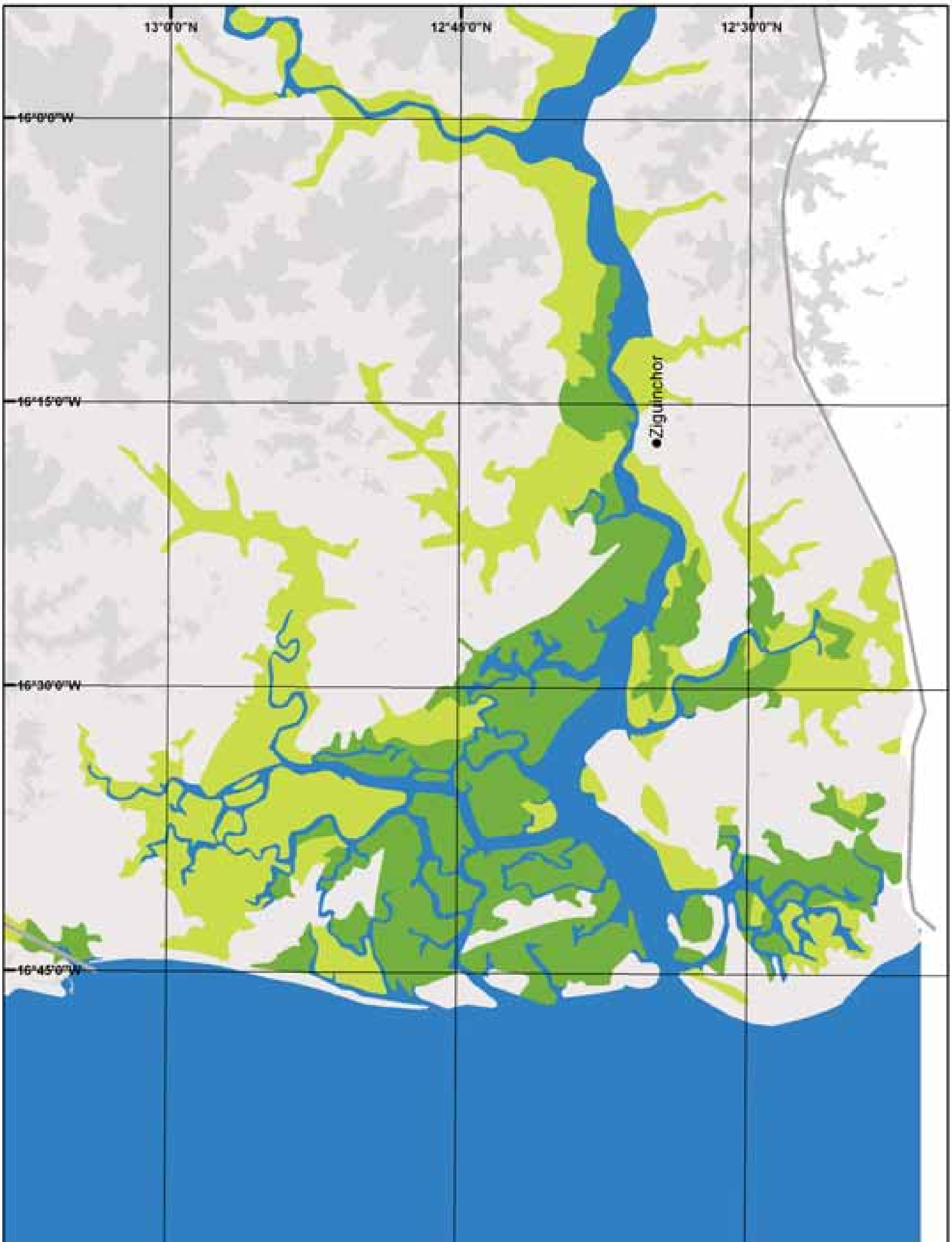


**Senegal and Gambia 1985 - D**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
teknr. 435-012a/12012007/ld
topography: ESRI

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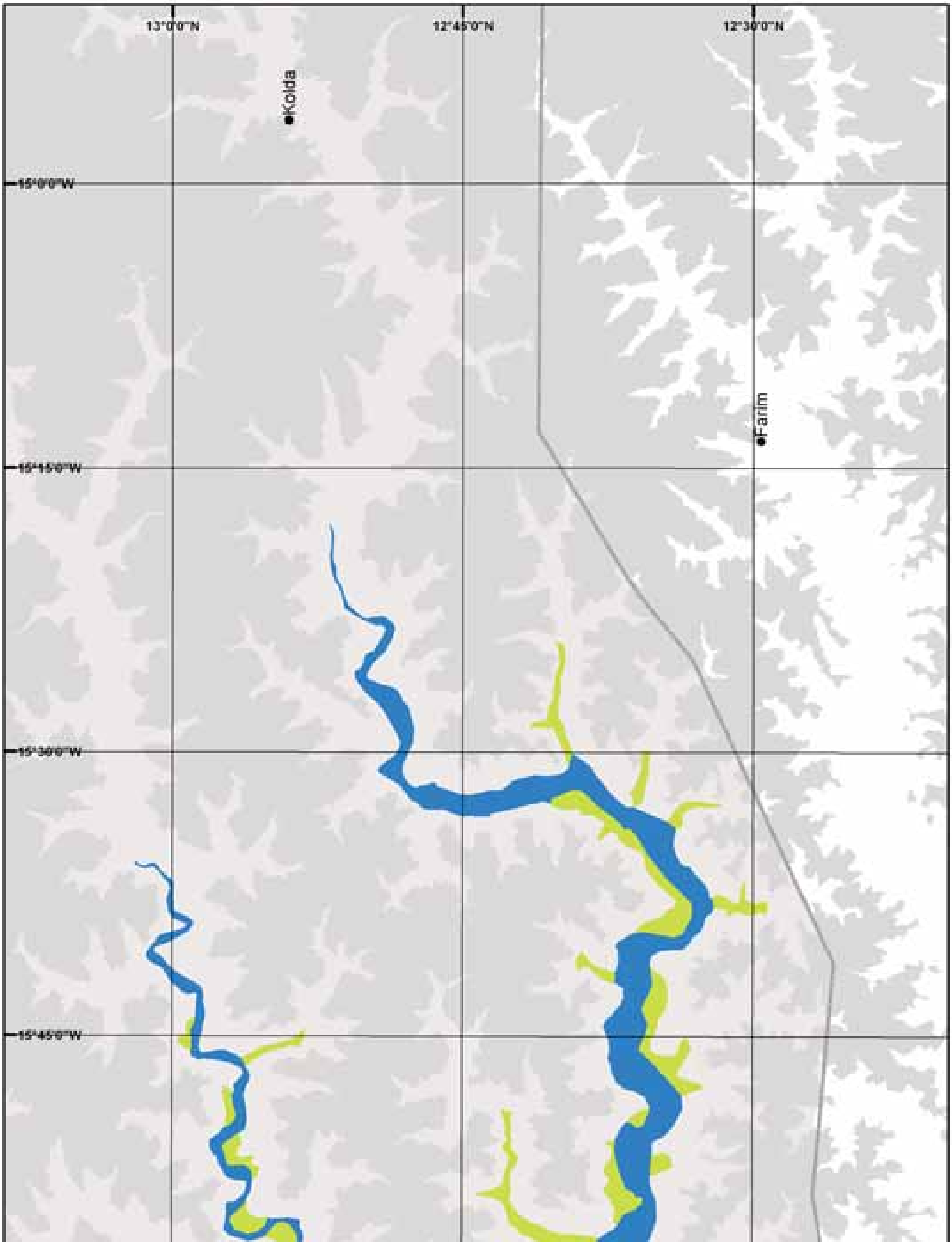


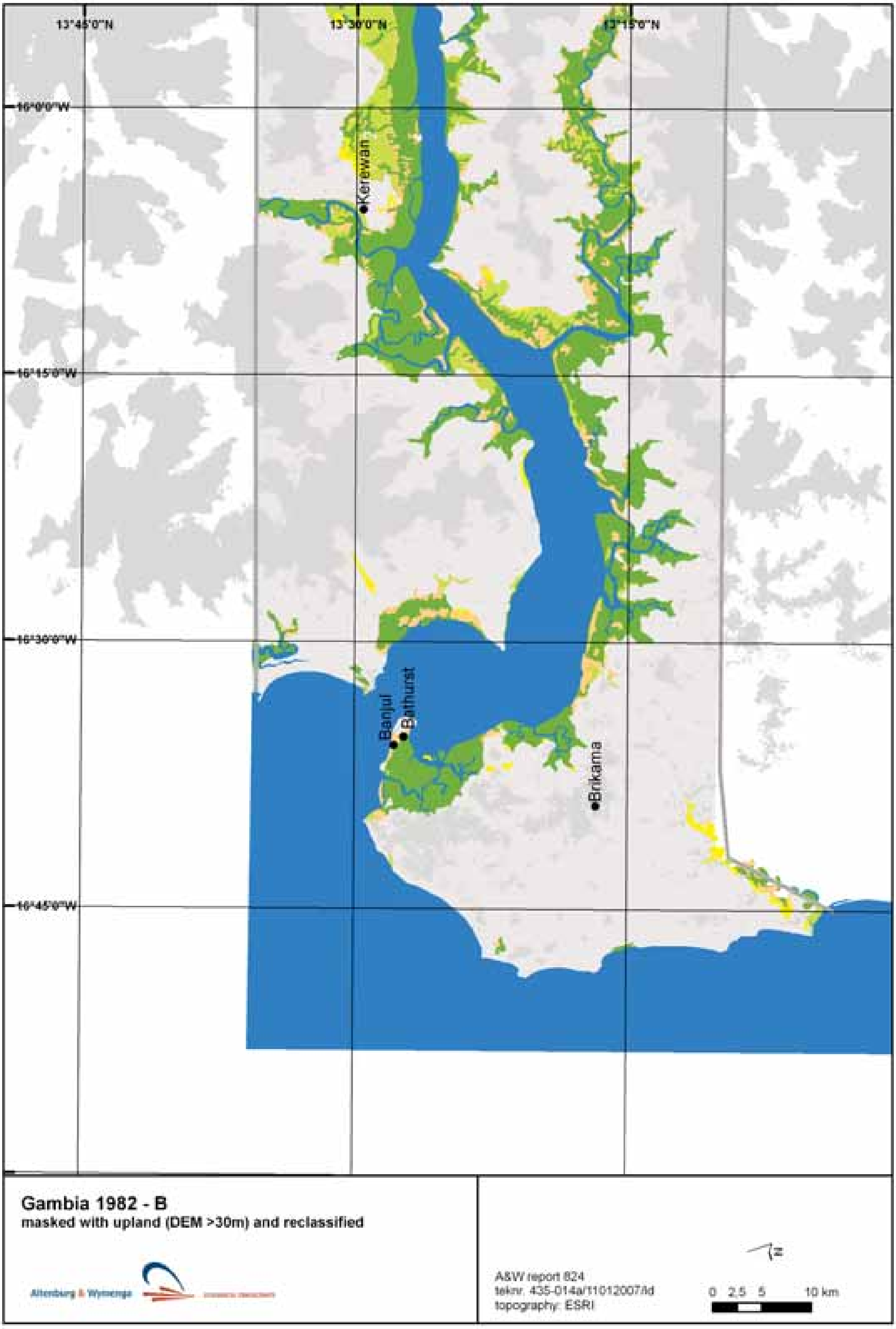

**Senegal and Gambia 1985 - E**
**masked with upland (DEM >30m) and reclassified**

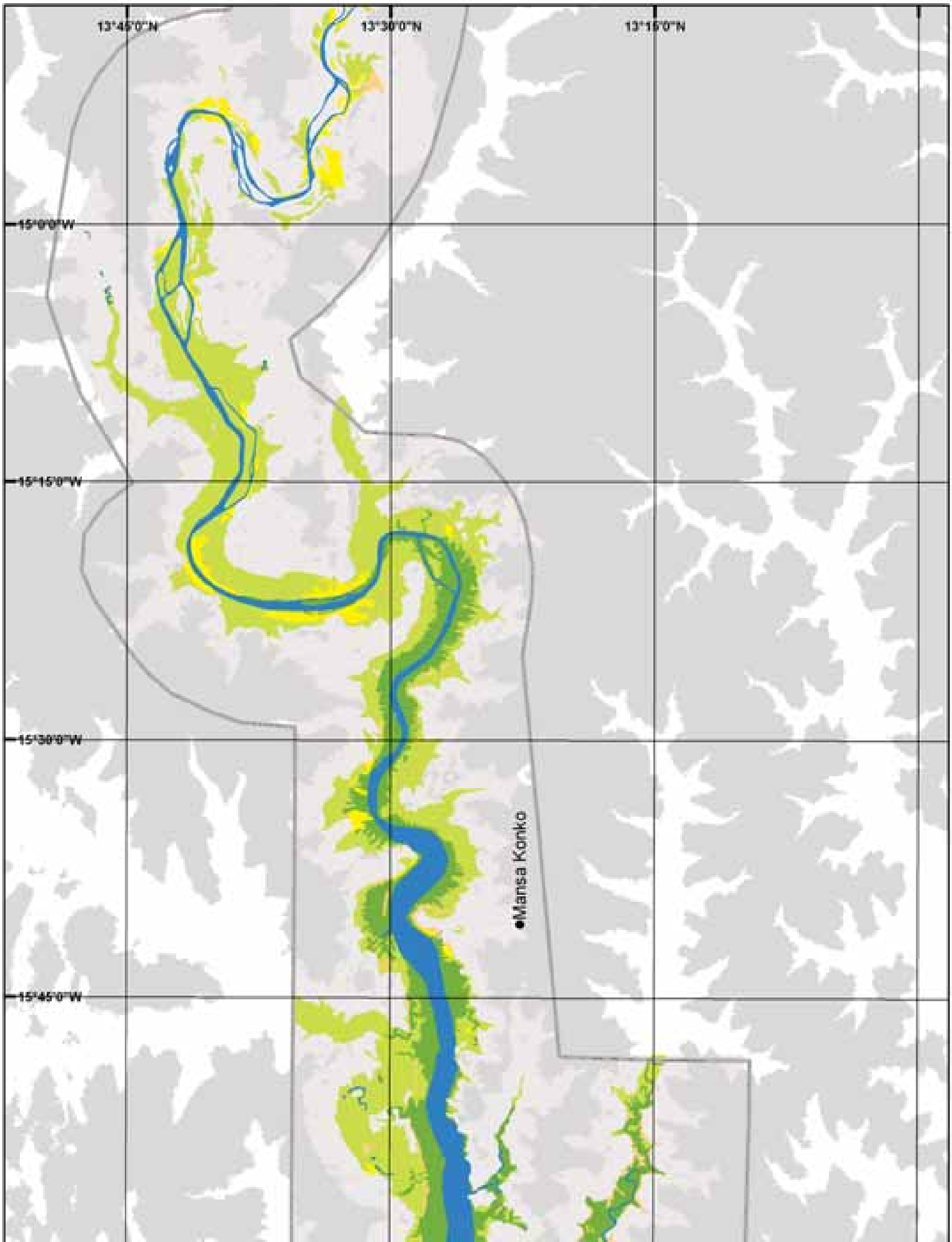
Altenburg & Wymenga

A&W report 824
teknr. 435-013a/11012007/ld
topography: ESRI

0 2.5 5 10 km

**Map app 4.3.**


13°45'0"N
13°30'0"N
13°15'0"N
16°0'0"W
16°15'0"W
16°30'0"W
16°45'0"W
Kerewan
Banjul
Bathurst
Brikama
Gambia 1982 - B
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr. 435-014a/11012007/ld
topography: ESRI
N
0 2,5 5 10 km




**Gambia 1982 - C**
**masked with upland (DEM >30m) and reclassified**

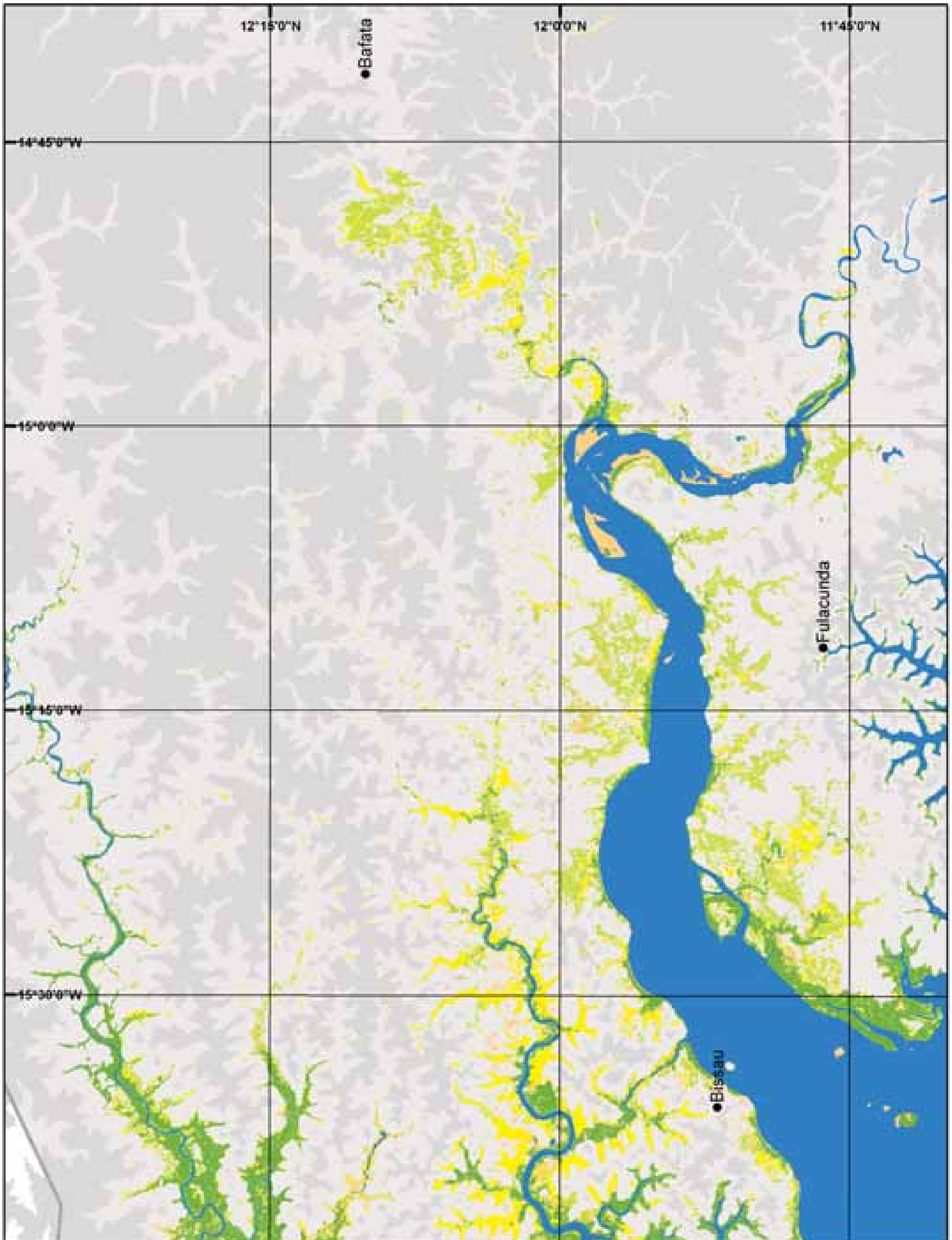
Altenburg & Wymenga

A&W report 824
teknr: 435-015a/11012007/ld
topography: ESRI

0 2.5 5 10 km

**Map app 4.4.**


12°15'0"N
12°0'0"N
11°45'0"N
15°45'0"W
16°0'0"W
16°15'0"W
16°30'0"W
Cacheu
Guinea Bissau 2006 - F
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr: 435-016a/11012007/ld
topography: ESRI
0 2,5 5 10 km

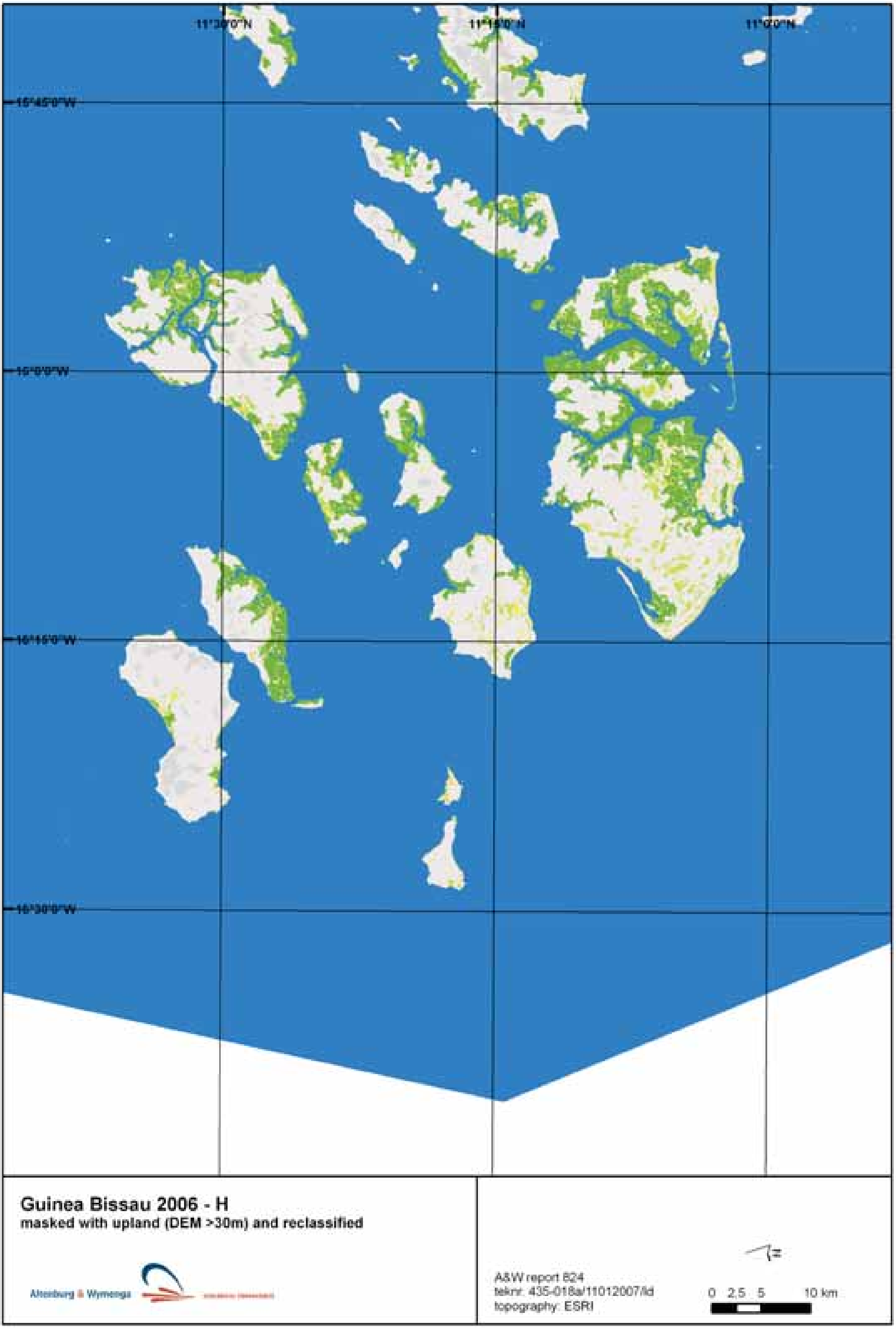



**Guinea Bissau 2006 - G**
**masked with upland (DEM >30m) and reclassified**

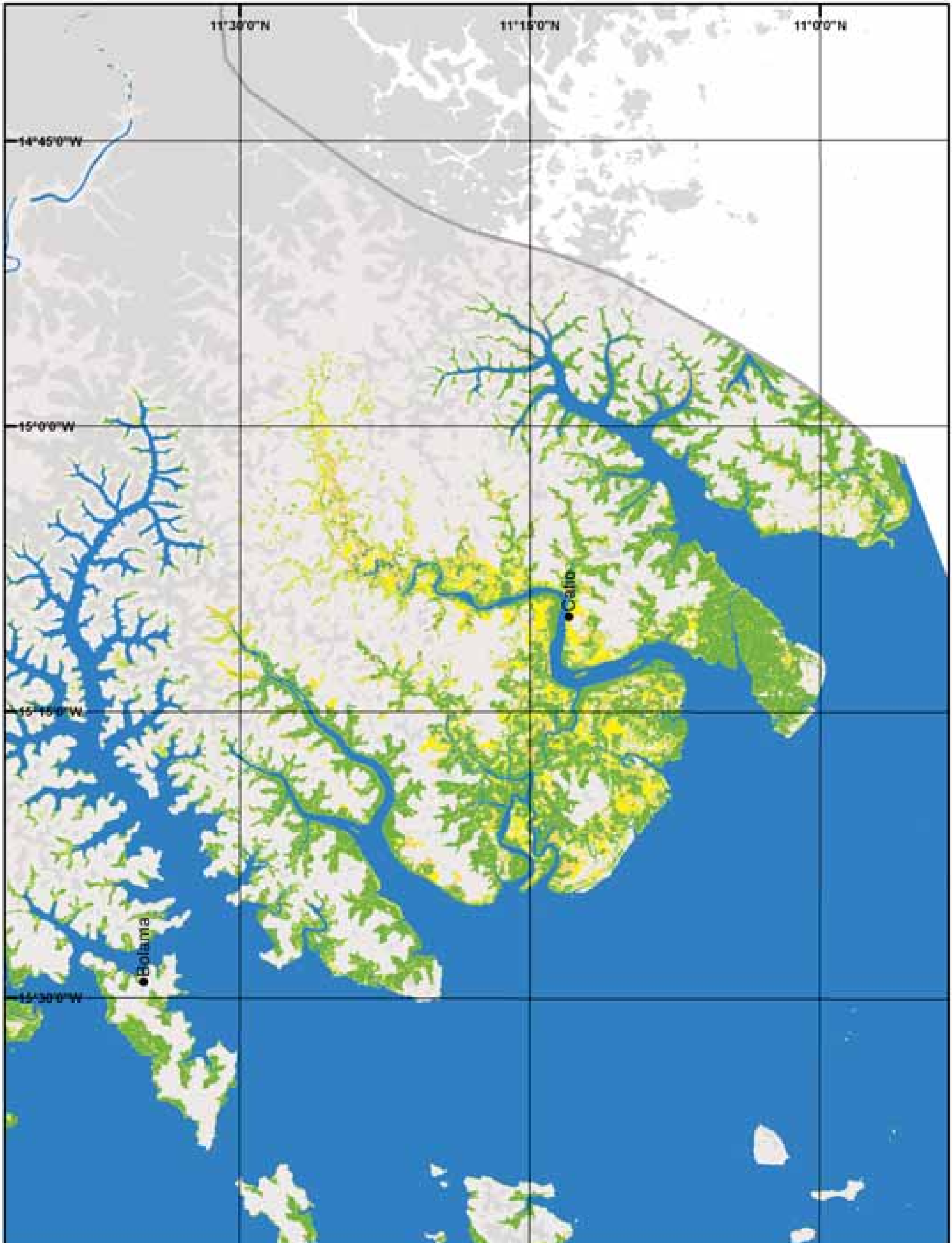
Altenburg & Wymenga

A&W report 824
teknr: 435-017a/11012007/ld
topography: ESRI

0 2.5 5 10 km



11°30'0"N
11°15'0"N
11°0'0"N
15°45'0"W
16°0'0"W
16°15'0"W
16°30'0"W
Guinea Bissau 2006 - H
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr: 435-018a/11012007/ld
topography: ESRI
0 2,5 5 10 km

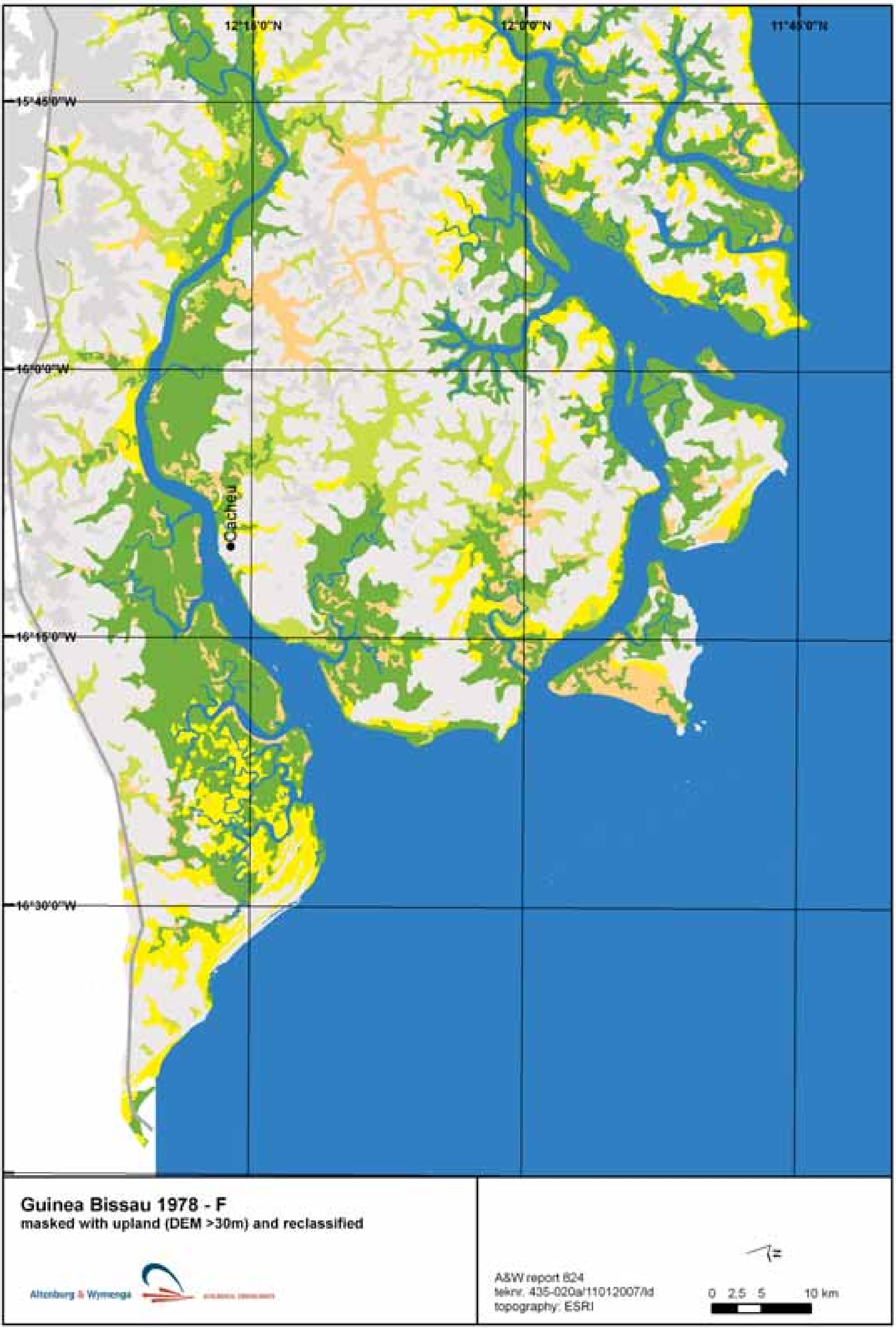


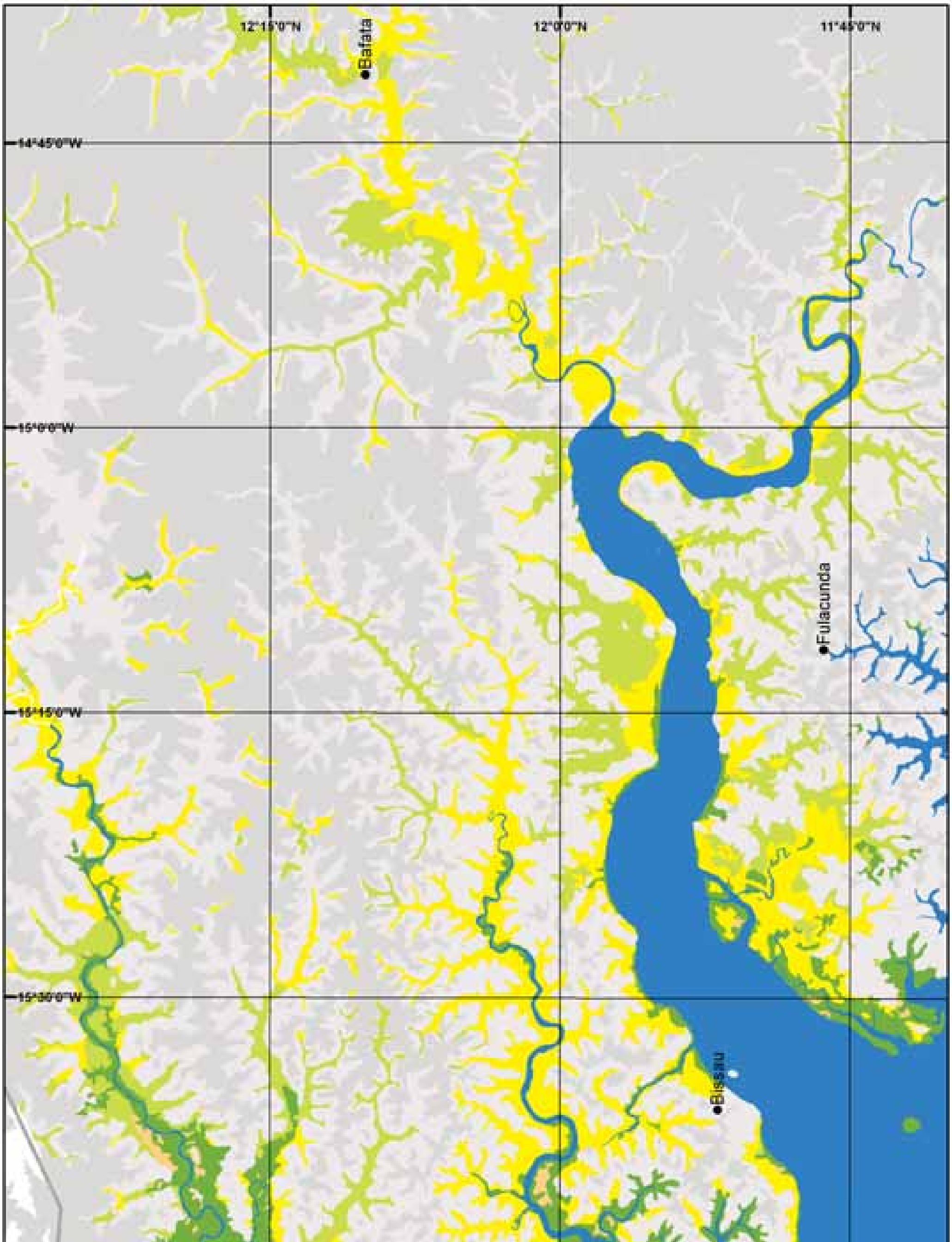

**Guinea Bissau 2006 - I**
**masked with upland (DEM >30m) and reclassified**

A&W report 824
teknr. 435-019a/11012007/ld
topography: ESRI

0 2.5 5 10 km

**Map app 4.5.**


12°15'0"N
12°0'0"N
11°45'0"N
15°45'0"W
16°0'0"W
16°15'0"W
16°30'0"W
Cacheu
Guinea Bissau 1978 - F
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr. 435-020a/11012007/ld
topography: ESRI
0 2.5 5 10 km



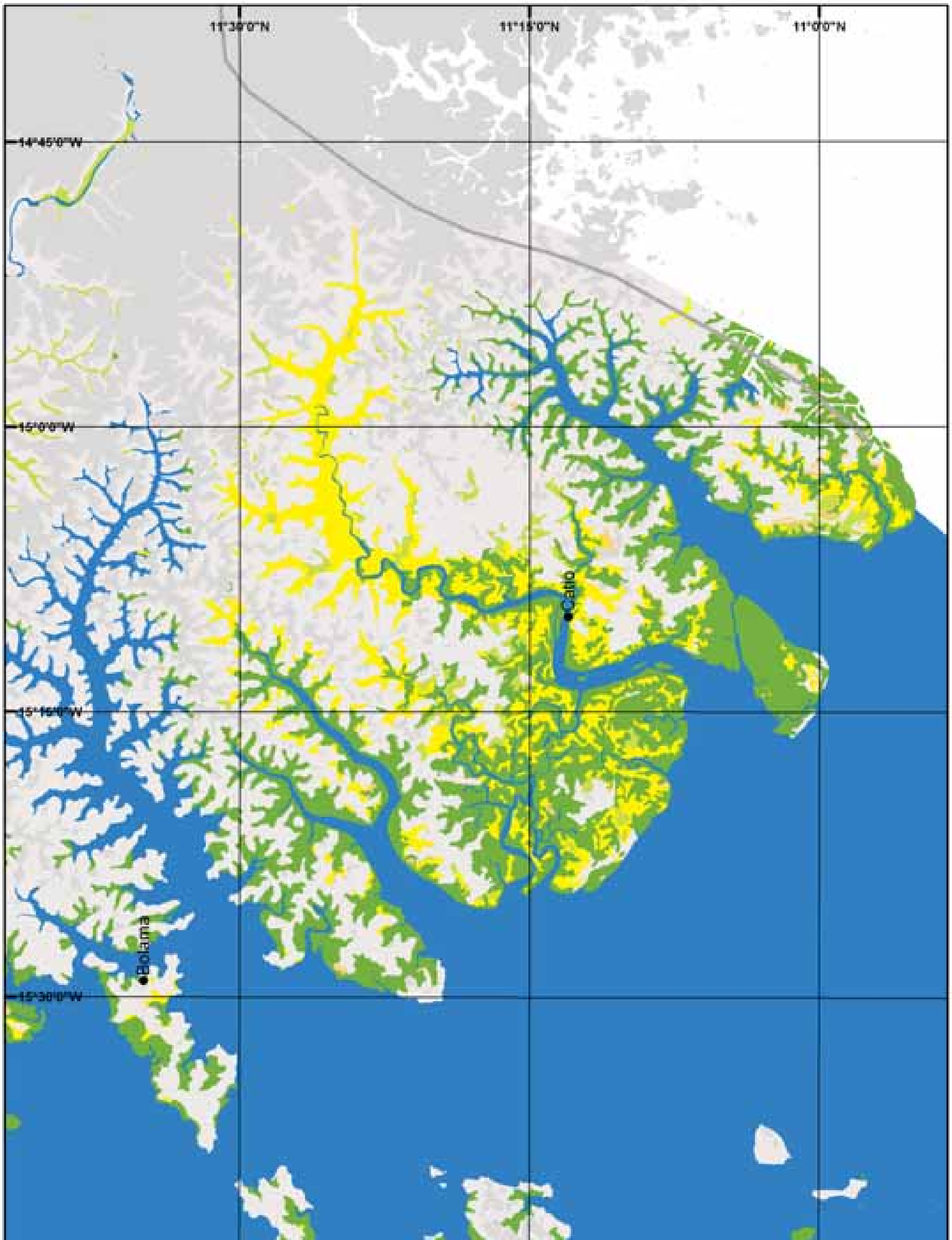

**Guinea Bissau 1978 - G**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
teknr: 435-021a/11012007/ld
topography: ESRI

0 2.5 5 10 km

11°30'0"N
11°15'0"N
11°0'0"N
15°45'0"W
16°0'0"W
16°15'0"W
16°30'0"W
Guinea Bissau 1978 - H
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr. 435-022/11012007/ld
topography: ESRI
0 2,5 5 10 km




**Guinea Bissau 1978 - I**
**masked with upland (DEM >30m) and reclassified**

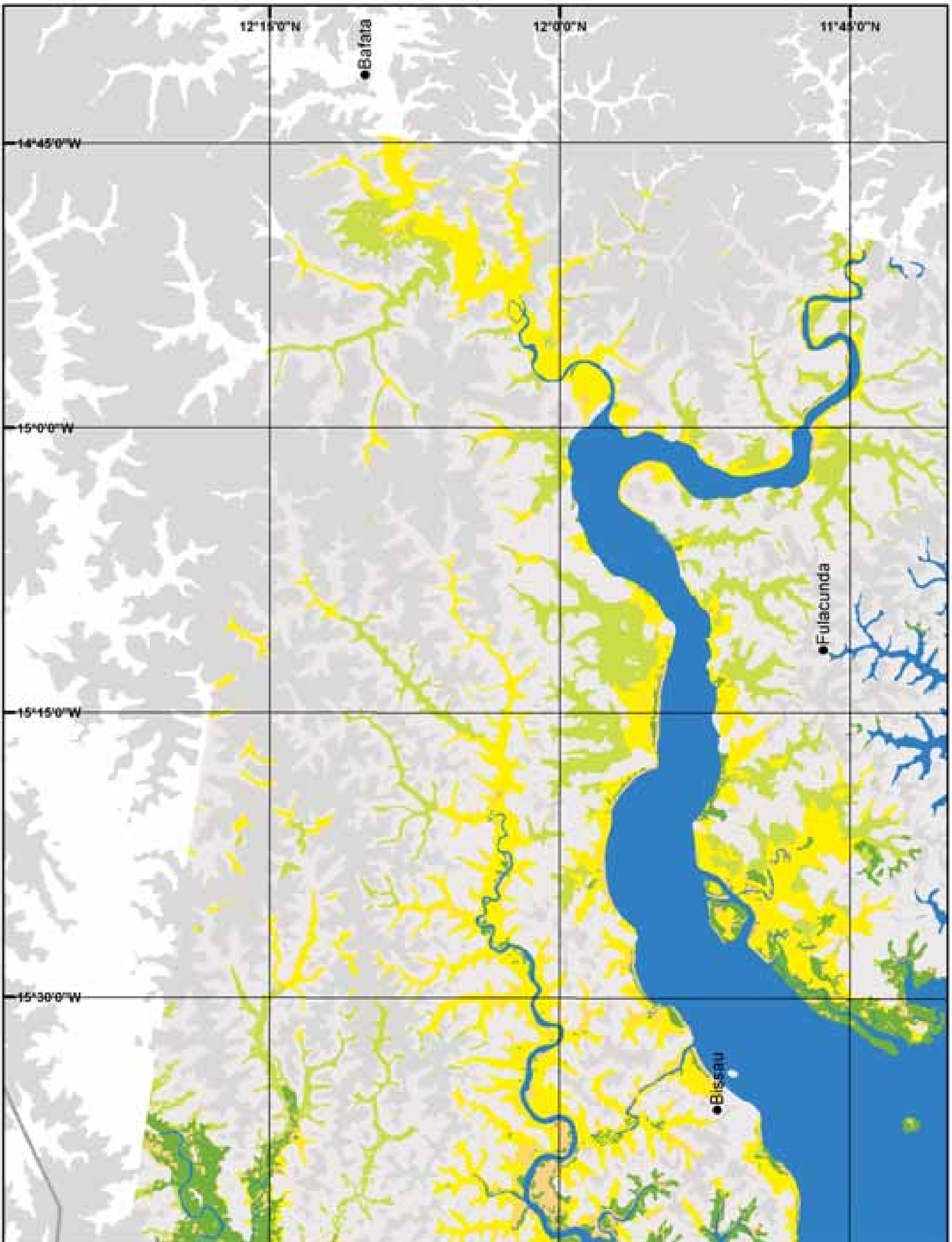
Altenburg & Wymenga

A&W report 824
teknr: 435-023a/11012007/ld
topography: ESRI

0 2,5 5 10 km

**Map app 4.6.**


12°15'0"N
12°0'0"N
11°45'0"N
15°45'0"W
16°0'0"W
16°15'0"W
16°30'0"W
Cacheu
Guinea Bissau 1993 - F
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr: 435-024a/11012007/ld
topography: ESRI
0 2,5 5 10 km



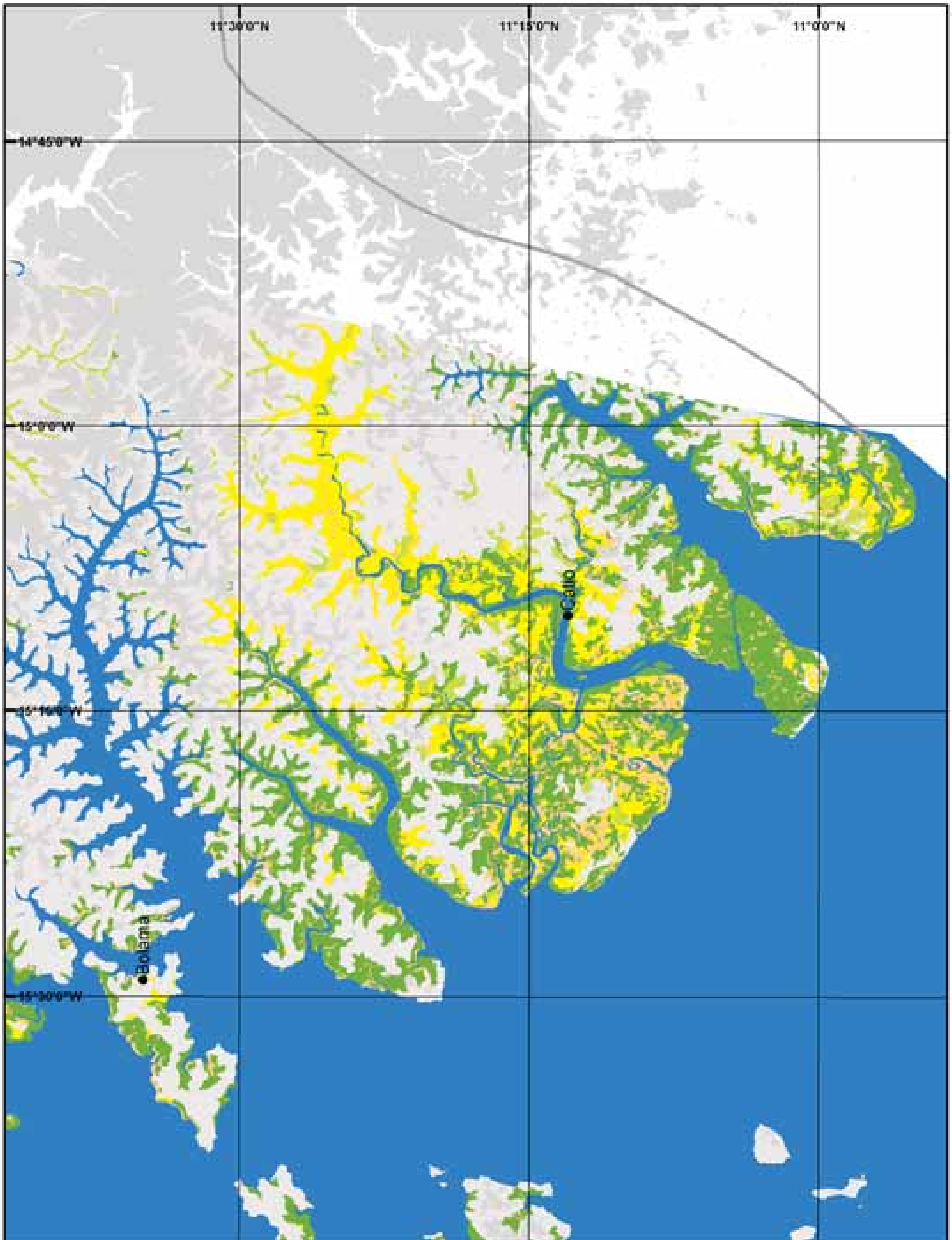

**Guinea Bissau 1993 - G**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
teknr: 435-025a/11012007/ld
topography: ESRI

0 2,5 5 10 km


11°30'0"N
11°15'0"N
11°0'0"N
15°45'0"W
16°0'0"W
16°15'0"W
16°30'0"W
Guinea Bissau 1993 - H
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr: 435-026a/11012007/ld
topography: ESRI
0 2.5 5 10 km



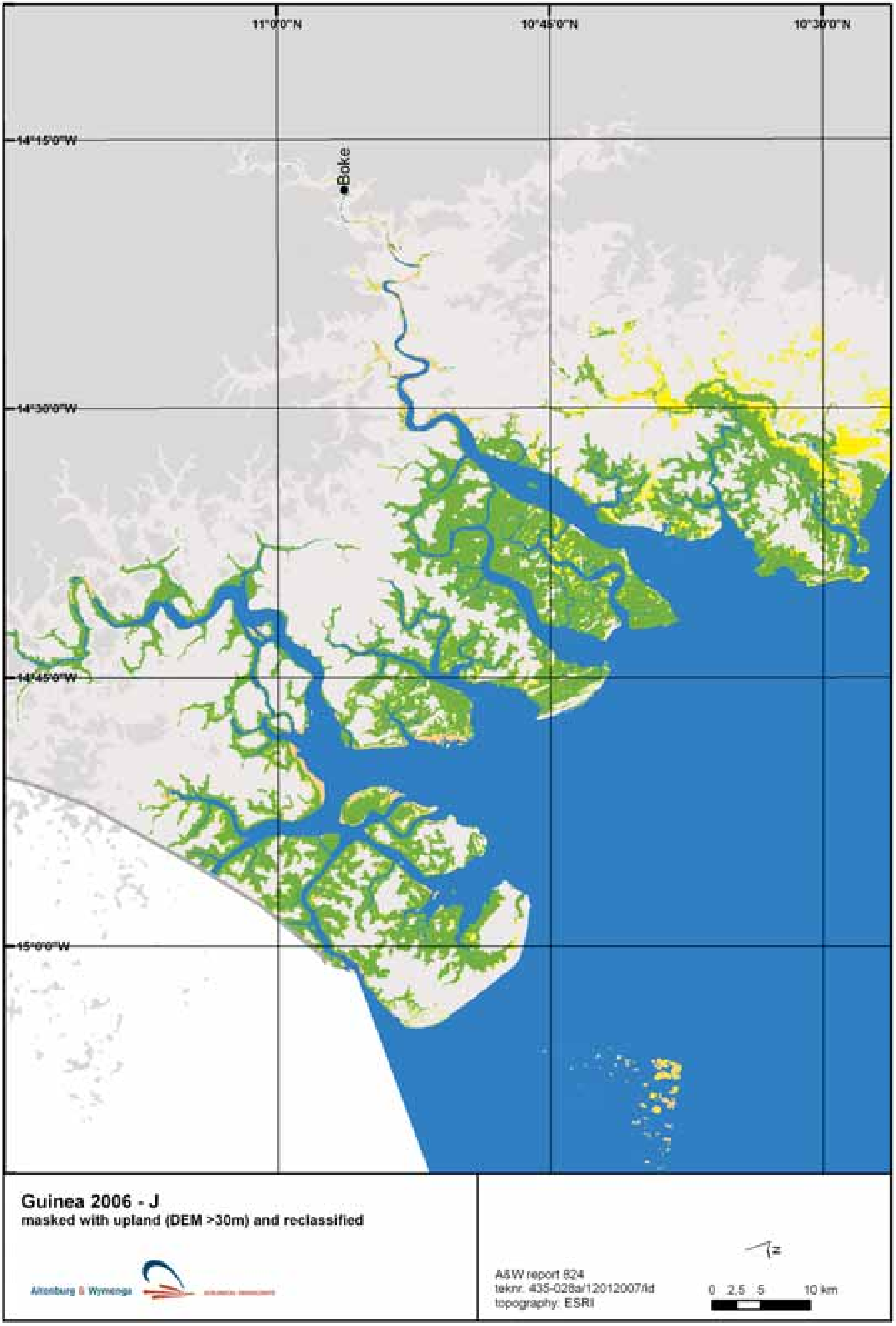

**Guinea Bissau 1993 - I**
**masked with upland (DEM >30m) and reclassified**

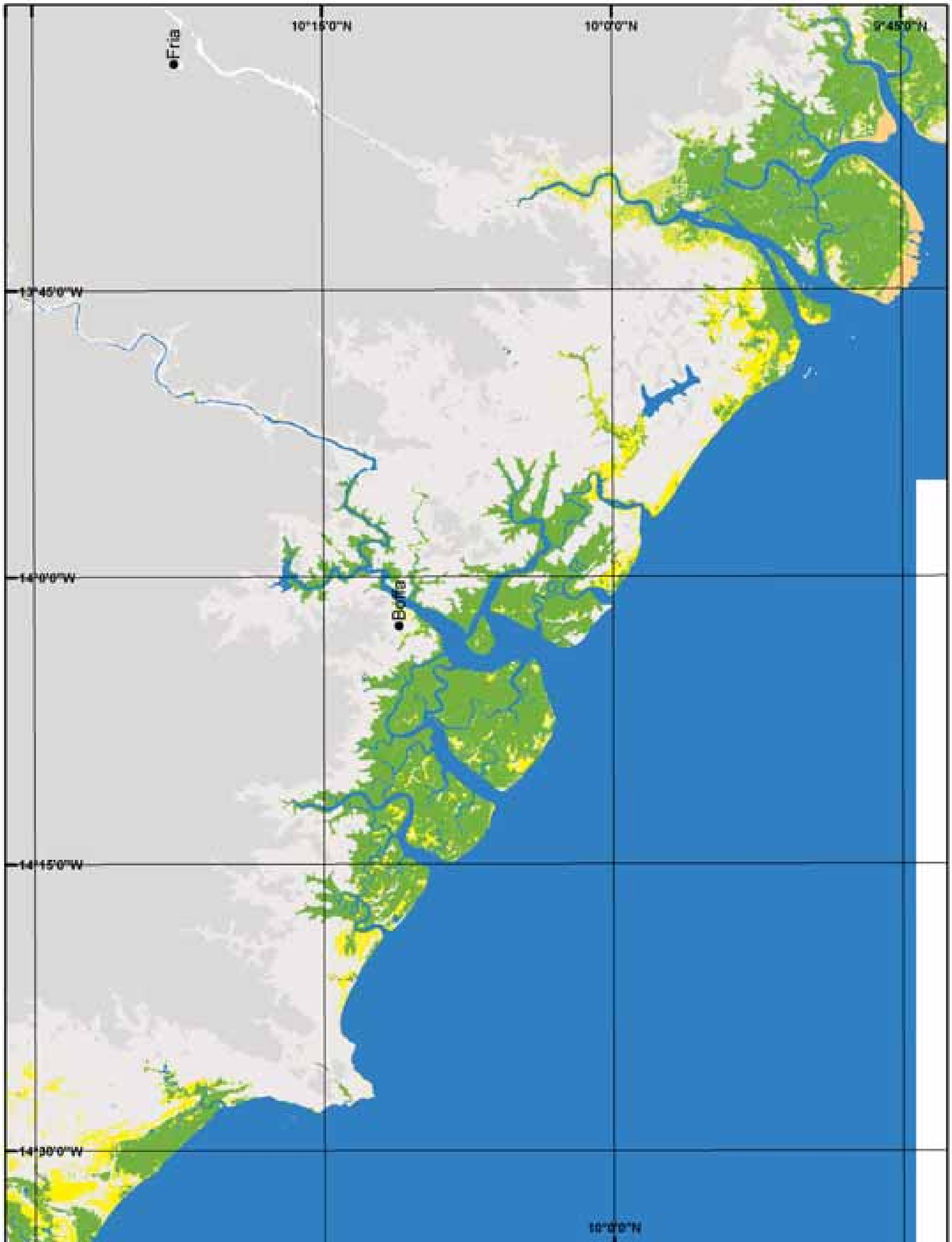
Altenburg & Wymenga

A&W report 824
teknr: 435-027a/11012007/ld
topography: ESRI

0 2.5 5 10 km

**Map app 4.7.**


11°0'0"N
10°45'0"N
10°30'0"N
14°15'0"W
14°30'0"W
14°45'0"W
15°0'0"W
Boke
Guinea 2006 - J
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr. 435-028a/12012007/ld
topography: ESRI
0 2,5 5 10 km

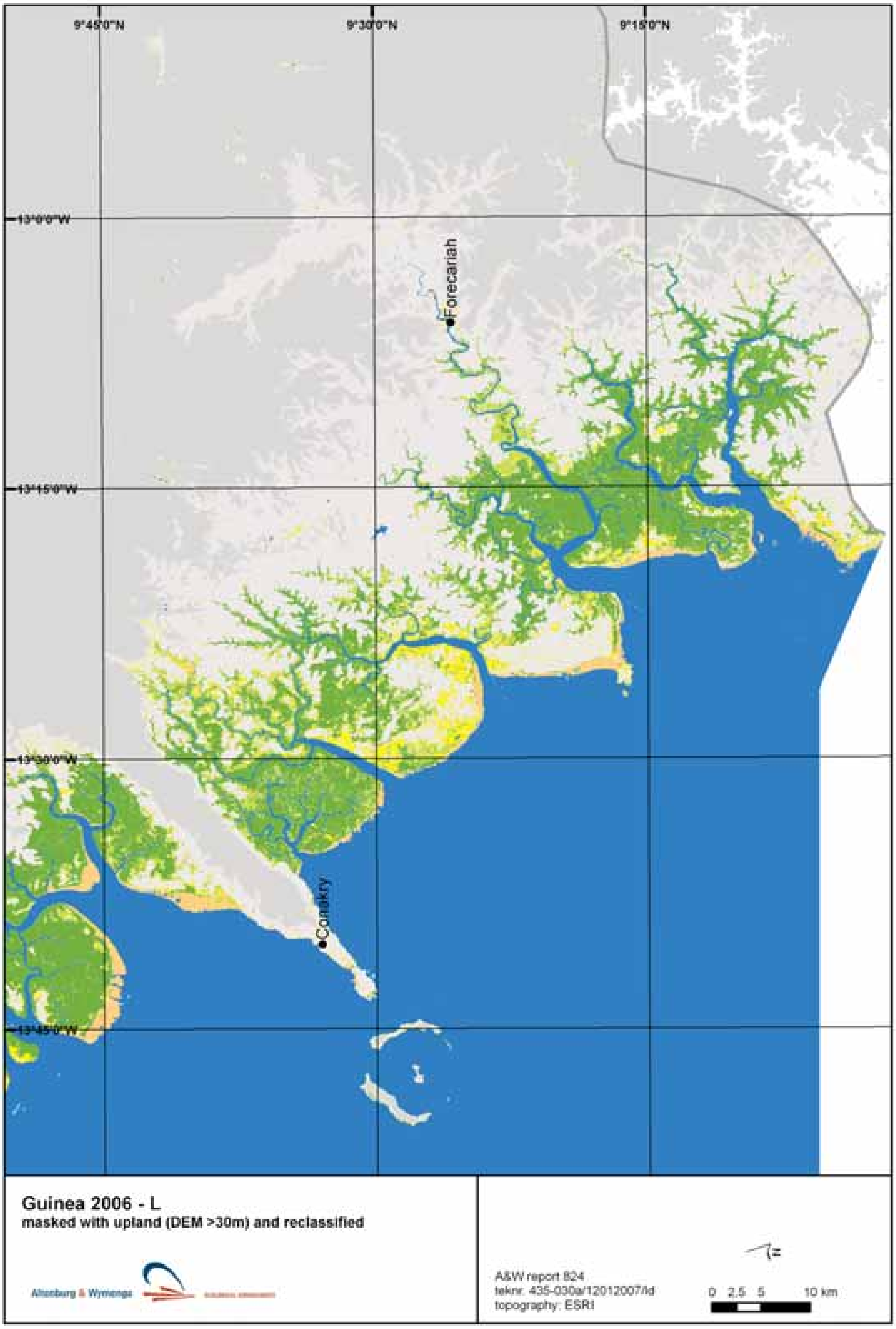



**Guinea 2006 - K**

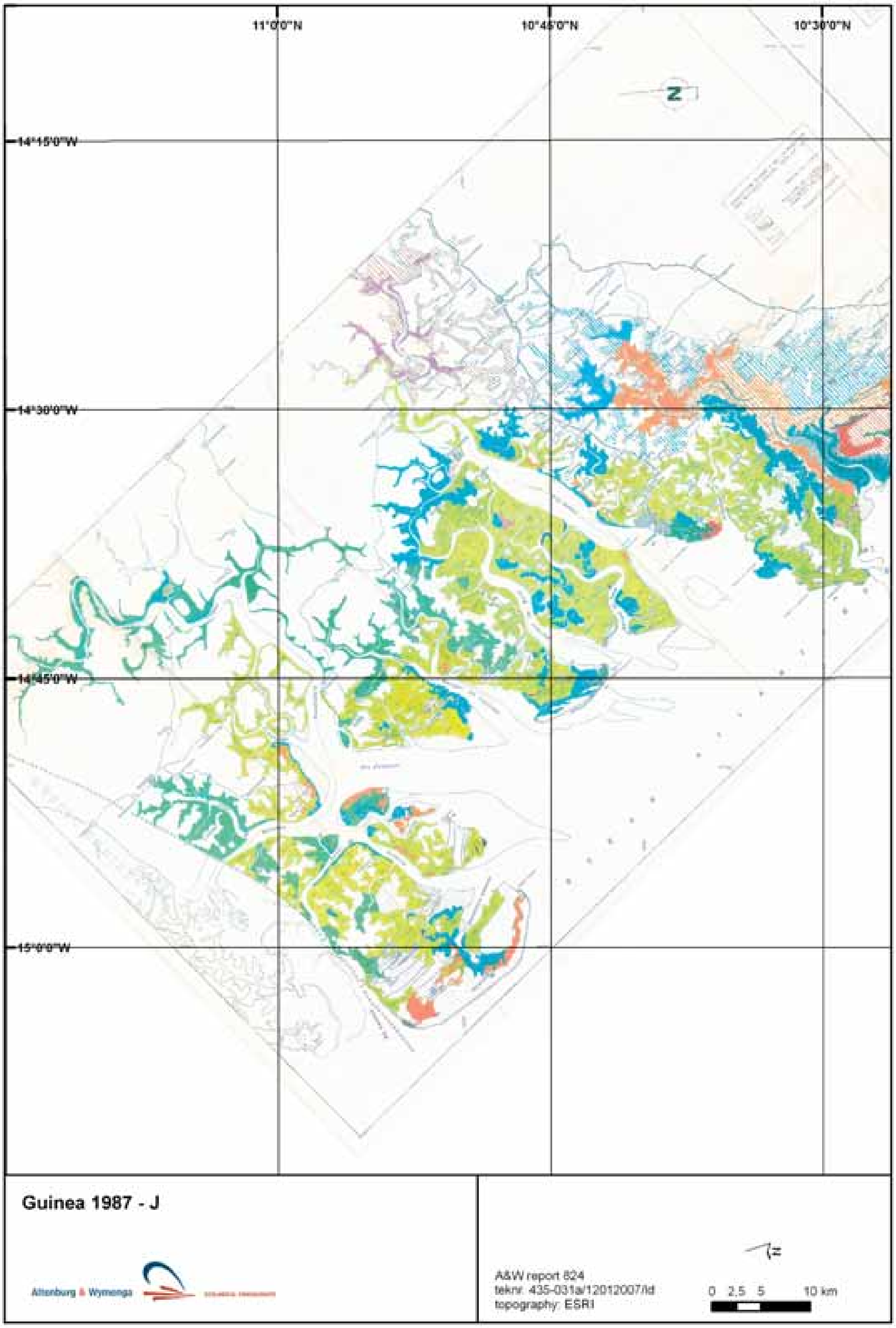
**masked with upland (DEM >30m) and reclassified**

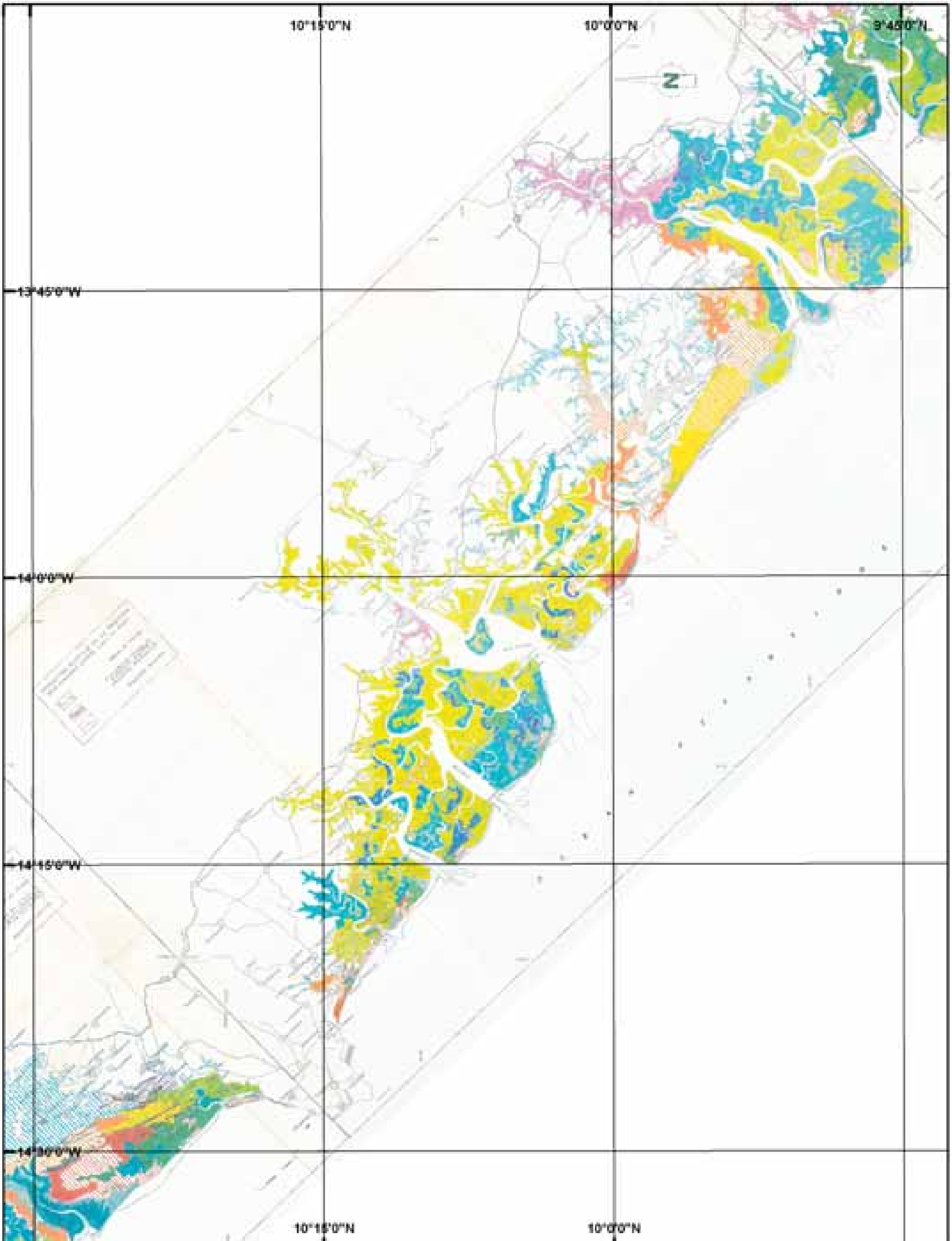
Altenburg & Wymenga

A&W report 824
teknr. 435-029a/12012007/ld
topography: ESRI


9°45'0"N
9°30'0"N
9°15'0"N
13°0'0"W
13°15'0"W
13°30'0"W
13°45'0"W
Forecariah
Conakry
Guinea 2006 - L
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr. 435-030a/12012007/ld
topography: ESRI
0 2,5 5 10 km

Map app 4.8.


11°0'0"N
10°45'0"N
10°30'0"N
14°15'0"W
14°30'0"W
14°45'0"W
15°0'0"W
Guinea 1987 - J
Altenburg & Wymenga
A&W report 824
teknr. 435-031a/12012007/ld
topography: ESRI
0 2,5 5 10 km

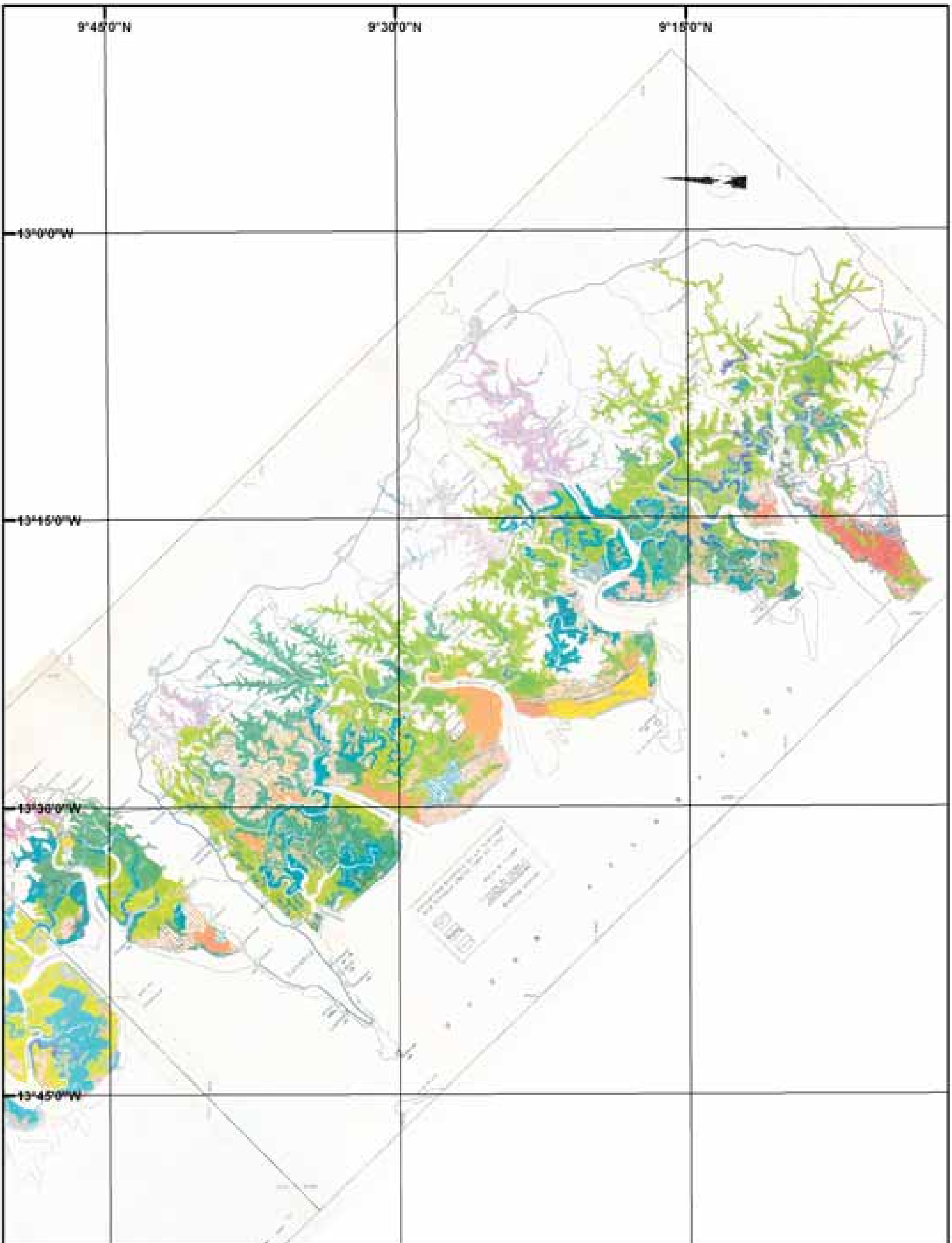



Guinea 1987 - K

Altenburg & Wymenga

A&W report 824
teknr. 435-032a/12012007/ld
topography: ESRI

0 2.5 5 10 km



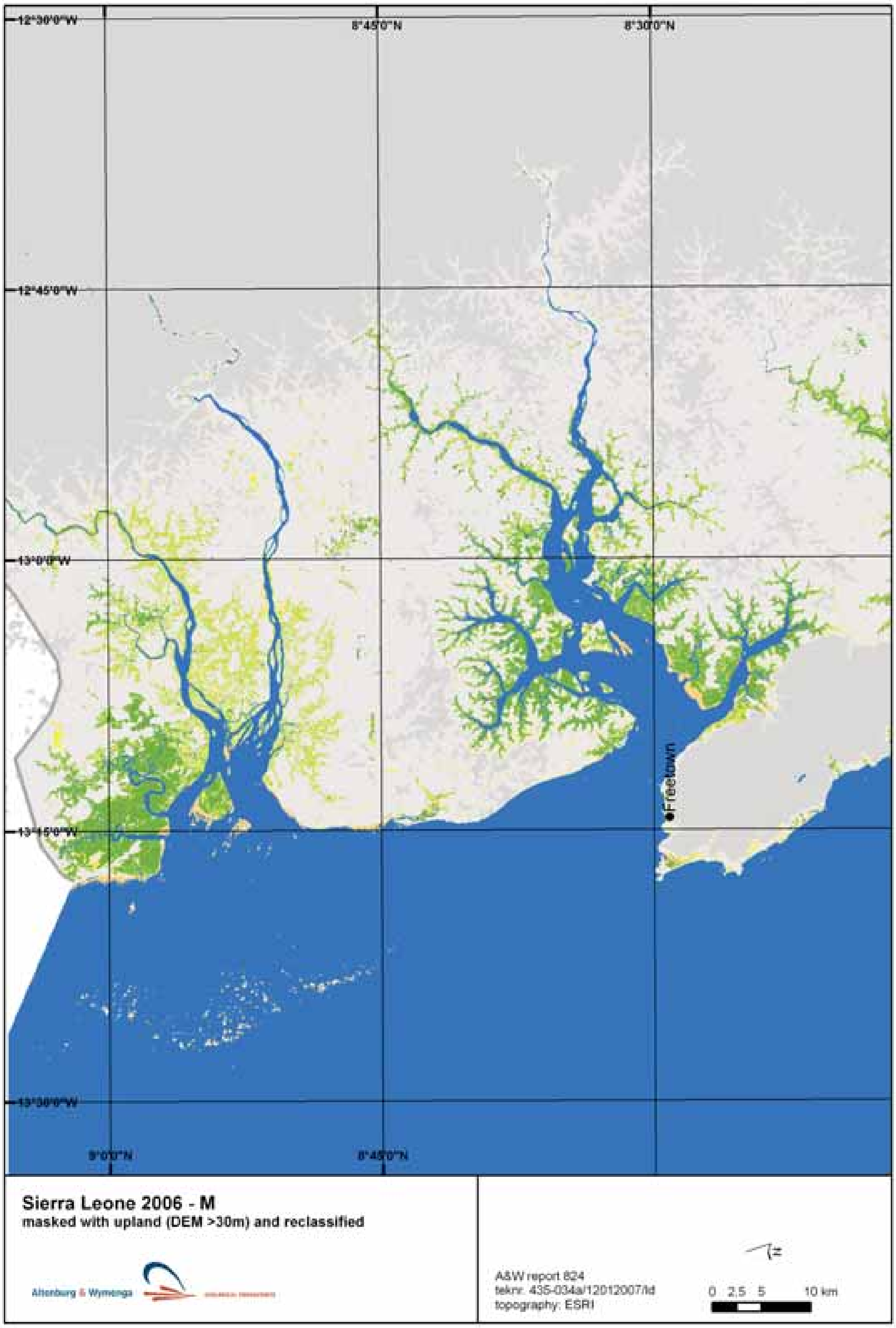

**Guinea 1987 - L**

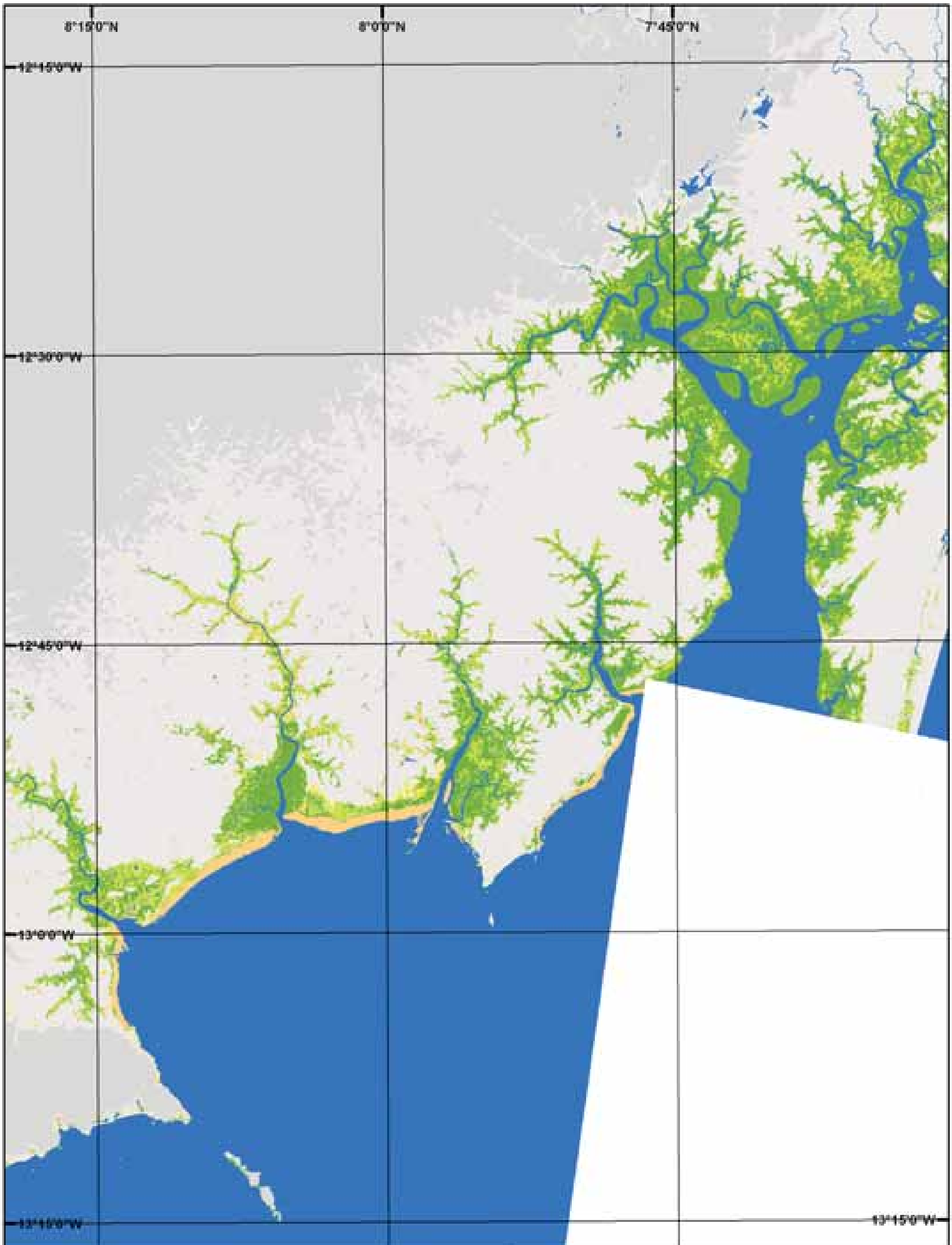
Altenburg & Wymenga

A&W report 824
teknr. 435-033a/12012007/ld
topography: ESRI

0 2,5 5 10 km

**Map app 4.9.**

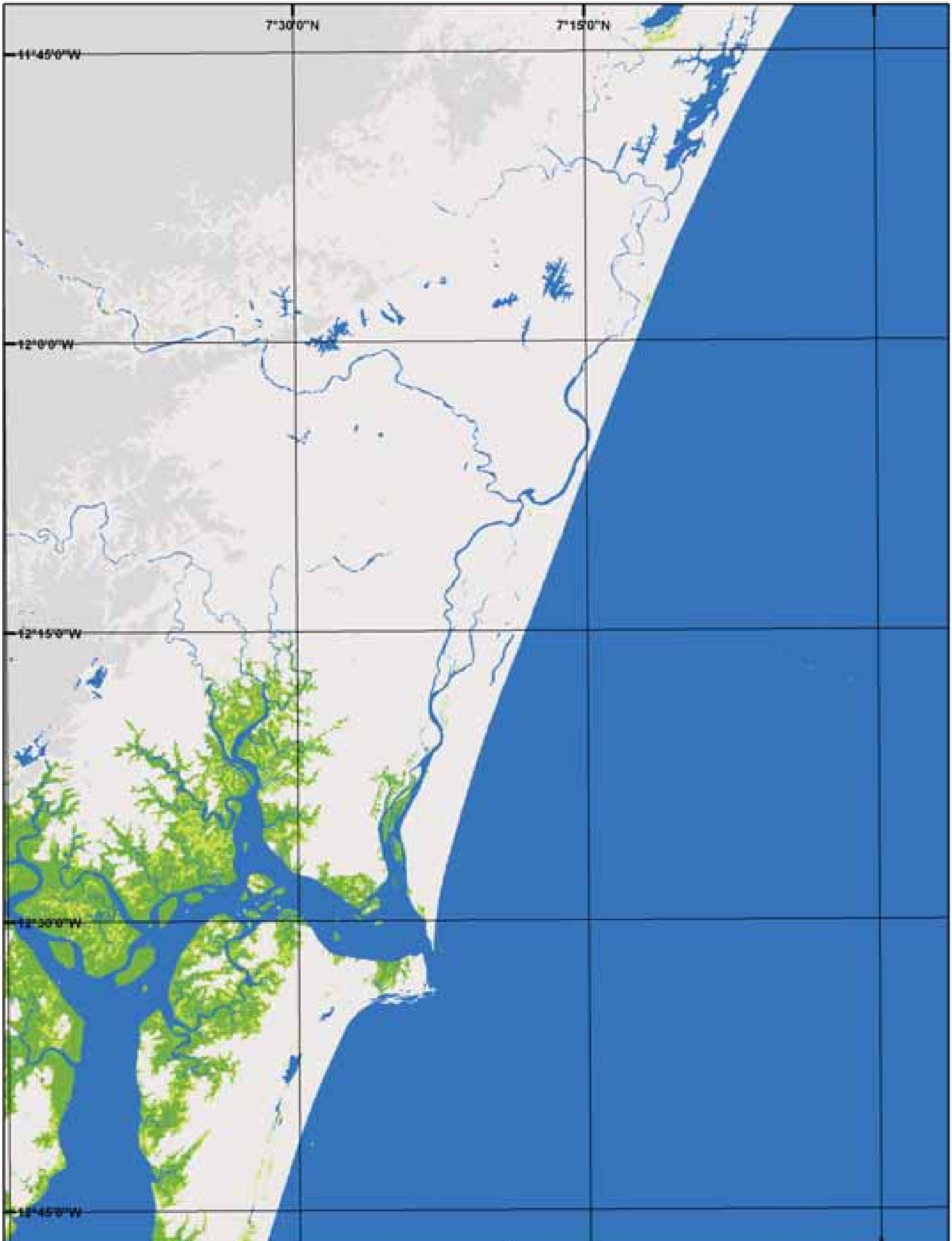

12°30'0"W
12°45'0"W
13°0'0"W
13°15'0"W
13°30'0"W
8°45'0"N
8°30'0"N
9°0'0"N
8°45'0"N
Freetown
Sierra Leone 2006 - M
masked with upland (DEM >30m) and reclassified
Altenburg & Wymenga
A&W report 824
teknr. 435-034a/12012007/ld
topography: ESRI
0 2.5 5 10 km




**Sierra Leone 2006 - N**
**masked with upland (DEM >30m) and reclassified**

A&W report 824
teknr. 435-035a/12012007/ld
topography: ESRI

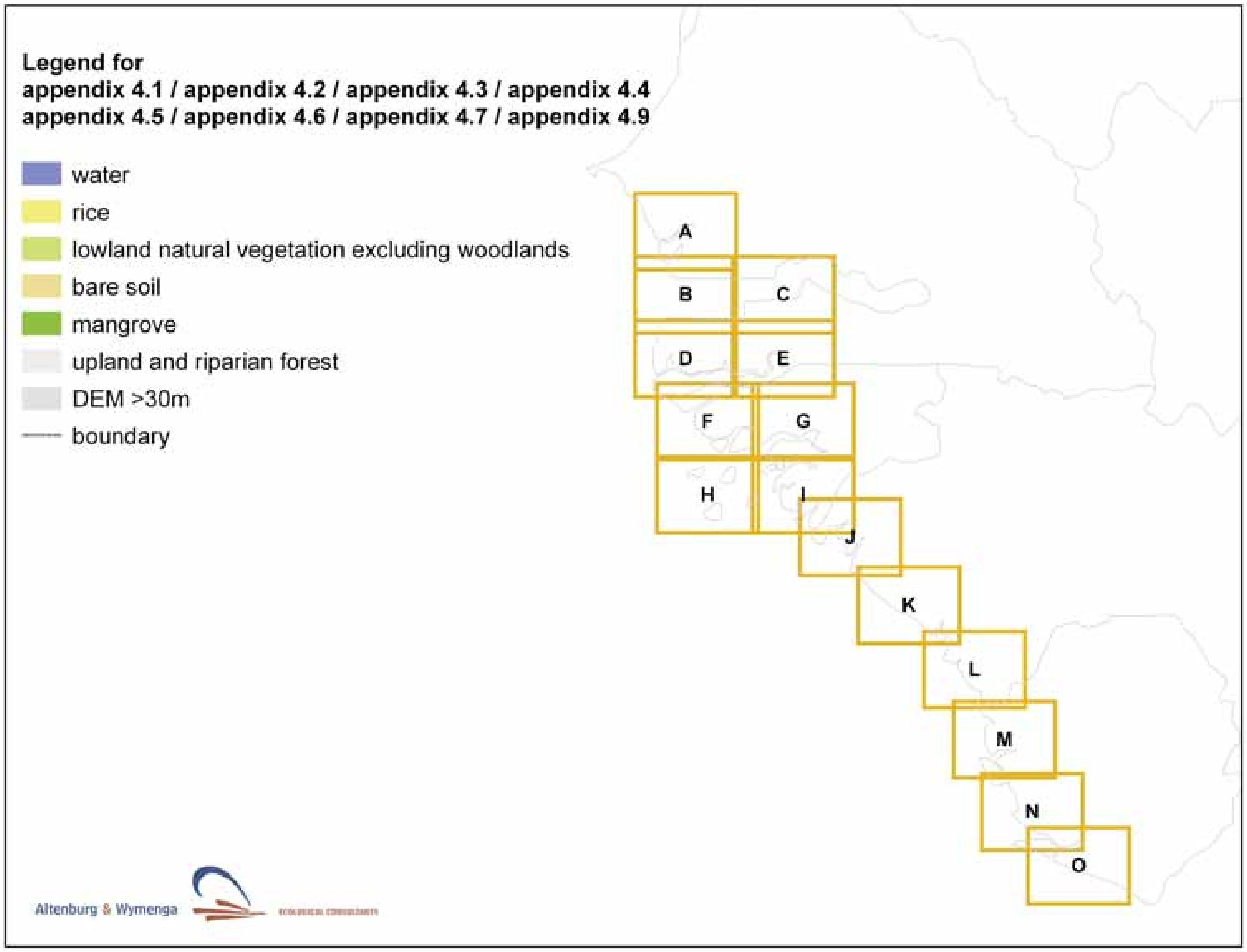
0 2.5 5 10 km




**Sierra Leone 2006 - O**
**masked with upland (DEM >30m) and reclassified**

Altenburg & Wymenga

A&W report 824
teknr. 435-036a/12012007/ld
topography: ESRI


Legend for
appendix 4.1 / appendix 4.2 / appendix 4.3 / appendix 4.4
appendix 4.5 / appendix 4.6 / appendix 4.7 / appendix 4.9
water
rice
lowland natural vegetation excluding woodlands
bare soil
mangrove
upland and riparian forest
DEM >30m
boundary
A
B
C
D
E
F
G
H
I
J
K
L
M
N
O
Altenburg & Wymenga

**Legend for appendix 4.8**

**REPUBLIQUE DE GUINEE**
**MINISTER DE L'AGRICULTURE ET DES RESOURCES ANIMALES**
**Direction Nationale**
**des Forêts et Chasse**
**Groups Interdisciplinaire**

**SCHEMA DIRECTEUR D'AMENAGEMENT DE LA MANGROVE**
**(S.D.A.M.)**
**FORMATIONS VEGETALES ET MISE EN VALEUR DES TERRES**
**Echelle 1/100.00e**
**SOCIETE D'ECO-AMENAGEMENT**
**SECA**
**Le Fanal - Port Juvenal**
**7, Esplanade de l'Europe**
**34000 MONTPELLIER FRANCE**
**Etude financée par le**
**Fond Europeen de Dévelopment**


Altenburg & Wymenga ECOLOGICAL CONSULTANTS

# Appendix 2

## Quality aspects of the current land-cover maps produced.

### Technical aspects

In the table below the dates are presented for the satellite images that have been used for the classifications produced in the current study.

**Table of Landsat TM satellite images used in the classification procedure in this study.**

| path | row | date |
|---|---|---|
| 201 | 54 | 24-03-2003 |
| | 55 | 12-01-1986 |
| | | 24-03-2003 |
| 202 | 53 | 03-01-1986 |
| | | 27-02-2003 |
| | 54 | 27-02-2003 |
| 203 | 52 | 04-04-2002 |
| | 53 | 02-02-2003 |
| 204 | 51 | 01-12-2000 |
| | | 30-04-2003 |
| | 52 | 04-12-2001 |
| | | 30-04-2003 |
| 205 | 50 | 04-11-1999 |
| | | 18-04-2002 |
| | 51 | 06-11-2000 |
| | | 18-04-2002 |

*Unsupervised classification*

We used an unsupervised classification with 400 classes based upon band 3, 4 and 5. The final, supervised, classification was obtained using the training sites in an iterative procedure by Ion Grigoras from the Danube Delta National Institute. A simple algorithm was used in which unsupervised classes were assigned to land cover-classes based upon the number of pixels, normalized by the area of the training site polygons. After each iteration, the supervisor judged whether for a given class of land cover extra training sites had to be invoked, by taking them from the pool of training sites originally meant for quality control. Based upon this scrutinous inspection, in some cases, training sites were removed because they appeared ambiguous. After the final iteration the land cover classes were grouped into four broad land cover classes (rice-fields, mangroves, other natural vegetation than mangrove, and bare areas).

### Other aspects of quality

*Ontological aspects*

Ontological aspects refer to the conceptualisation of the land cover classes. Land cover classification schemes are not determined by the reflectance properties of land cover and their inferred relationship with biology alone. Rather, their specification combines policy objectives at regional, national or international levels with the individual and institutional objectives of those charged with creating the derived land cover map to inform policy (Comber *et al.* 2005). Therefore we describe shortly the ontological aspects that are relevant for the interpretation of the maps produced by us.

It was the biologists who determined what the features of interest were. The aim was to estimate cover of rice fields, bare areas and mangrove vegetation in the lowlands of the Rice and Mangrove Ecoregion. The perspective was guided by the ultimate aim to link changes in the land cover in these lowland areas to changes in those bird populations that depend on these wetlands.

*Meaning of the classes and integrity of the units*

Land cover classes have been defined from a botanical point of view.

- Rice fields refer to areas that have been used in the current dry season for cultivating rice. They include those fields where rice had been planted but where harvest had failed. This latter group is likely to be confused with the bare areas.
- Bare areas are all without vegetation. The bare intertidal and upper tidal areas are the most

**The error matrices for the classification presented in map 4.1 per country. Numbers in the matrix represent numbers of pixels (sampled as clusters of pixels). For each class the correct % is added. The overall accuracy is 58%. The land cover legend units are explained in this appendix.**

| | | observed landcover | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| country | classified data | bare | mangrove | lowland natural vegetation | rice | upland | water | row total | users accuracy |
| Senegal | bare | 4404 | 170 | 47 | 0 | 3 | 362 | 4986 | 88% |
| | mangrove | 299 | 1636 | 1 | 22 | 0 | 0 | 1958 | 84% |
| | lowland natural vegetation | 91 | 41 | 173 | 68 | 0 | 7 | 380 | 46% |
| | rice | 46 | 21 | 43 | 977 | 674 | 0 | 1761 | 55% |
| | upland | 132 | 24 | 444 | 605 | 11150 | 1 | 12356 | 90% |
| | water | 59 | 4 | 0 | 0 | 0 | 666 | 729 | 91% |
| | producers accuracy | 88% | 86% | 24% | 58% | 94% | | | |
| The Gambia | bare | 497 | 40 | 87 | 31 | 25 | 18 | 698 | 71% |
| | mangrove | 42 | 1766 | 16 | 30 | 3 | 6 | 1863 | 95% |
| | lowland natural vegetation | 35 | 73 | 613 | 221 | 39 | 28 | 1009 | 61% |
| | rice | 127 | 85 | 232 | 515 | 2 | 4 | 965 | 53% |
| | upland | 1256 | 29 | 763 | 233 | 6262 | 43 | 8586 | 73% |
| | water | 2 | 2 | 17 | 7 | 19 | 118 | 165 | 72% |
| | producer saccuracy | 25% | 89% | 35% | 50% | 99% | | | |
| Guinea-Bissau | bare | 1002 | 226 | 313 | 46 | 69 | 10 | 1666 | 60% |
| | mangrove | 168 | 1262 | 234 | 115 | 27 | 4 | 1810 | 70% |
| | lowland natural vegetation | 449 | 93 | 602 | 316 | 107 | 1 | 1568 | 38% |
| | rice | 775 | 101 | 492 | 2317 | 63 | 25 | 3773 | 61% |
| | upland | 486 | 95 | 318 | 996 | 2872 | 6 | 4773 | 60% |
| | water | 13 | 25 | 23 | 0 | 0 | 668 | 729 | 92% |
| | producers accuracy | 35% | 70% | 30% | 61% | 92% | | | |
| Guinea | bare | 0 | 11 | 0 | 0 | 0 | 0 | 11 | 0% |
| | mangrove | 2059 | 1115 | 27 | 130 | 0 | 0 | 3331 | 33% |
| | lowland natural vegetation | 77 | 53 | 201 | 117 | 5 | 4 | 457 | 44% |
| | rice | 2296 | 666 | 468 | 2729 | 40 | 0 | 6199 | 44% |
| | upland | 1785 | 36 | 2210 | 11739 | 4353 | 13 | 20136 | 22% |
| | water | 146 | 201 | 3 | 49 | 124 | 1106 | 1629 | 68% |
| | producers accuracy | 0% | 54% | 7% | 18% | 96% | | | |

important components, but there are also bare areas within the rice polders and upland.

- Mangrove vegetation refers to stands of mangrove with cover above 25%. Since mangroves share boundaries with other natural vegetation, intertidal areas and open water on fine scales, there will be confusion with these classes. There are a number of species of mangrove, and a diversity in mangrove environments (Bertrand 1999). However, variations in species composition and vegetation cover are not taken into account in the maps presented in this study.
- Other natural vegetation in the lowlands refers to plant communities other than rice or mangrove vegetation. These are vegetation types growing on upper tidal areas, in valleys, behind dams or within rice-polders. Examples are *Cyper* vegetations (*Eleocharis*, *Schoenoplectus*, *Fimbristillis*), grass stands (*Sporobolis*, *Paspalum*), Salt-tolerant communities (*Sesuvium*), wild rice and aquatic vegetation (*Nymphea*, *Nunephar*). Some communities within this class grow in rice fields that are left fallow. Since ground truthing data have been collected two to four years after the image was taken, and since the reflectance characteristics of some phenological stages of some of these communities overlap with those from rice fields, there will inevitably be confusion between these classes.
- The upland area has been outside our scope, and thus refers to a very heterogeneous class of forests, shrubs, grasslands, cultivation areas and settlements. They generally are dry and not of relevance for wetland-related species.

# Appendix 3

## Available estimates of mangrove cover and their source.

**Table presenting the available estimates of mangrove and rice cover collected by Willy & Fortuna (2003), and the new data presented in this study.**

**The column 'mangrove trend' indicates whether data has been used to calculate trends over time (1 = yes, 0 = no). It refers to those data points that were judged by Wilkie & Fortuna (2003) to be reliable, unless we were able to replace them by estimates from an even more reliable, primary, source. The data have been sorted by this column, in addition to sorting by country and year.**

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| Guinea | 1980 | 285000 | | Hughes, R.H. and Hughes, J.S. 1992. A Directory of African Wetlands. IUCN, Gland, Switzerland and Cambridge, UK/UNEP, Nairobi, Kenya/WCMC, Cambridge, UK. 820 pp. | 1 | Analysis of maps and/or remote sensing imageries. No specific scale is given. | Wilkie and Fortuna |
| Guinea | 1987 | 260000 | 31200 | Altenburg, W. 1987. Waterfowl in West African Coastland Wetlands: a summary of current knowledge of the occurence of waterfowl in wetlands from Guinea-Bissau to Cameroon and a bibliography of information sources. Zeist, The Netherlands: Stichting WIWO (Werkgroep International Wad- en Watervogelonderzoek). | 1 | Primary source is SECA/CML 1987. Year is publ. year. Rice area is the productive area (40% of 78000 ha) | |
| Guinea | 1995 | 296300 | | Saenger, P. and Bellan, M.F. 1995. The Mangrove vegetation of the Atlantic coast of Africa. Universitè de Toulouse Press, Toulouse 96 pp | 1 | Secondary reference, no primary source provided. The "Year" is publication year. | Wilkie and Fortuna |
| Guinea | 1957 | 400000 | | Rouanet. 1957. Cited in: Kaba, B. 2001. La zone mangrovienne de Guinée. Proceedings of the: Halieutique : complexité et décision - 5ème forum halieumétrique, Lorient, Palais des Congrès, 26-28 juin 2001. 2003 | | | Wilkie and Fortuna 2003 |
| Guinea | 1965 | 350000 | | Kaba, B. 2001. La zone mangrovienne de Guinée. In: Proceedings of the: Halieutique: complexité et decision. 5ème forum halieumétrique. Lorient, Palais des Congrès, 26-28 juin 2001. http://www.agrorennes.educagri.fr/scripts/fr/C | 0 | Secondary reference, no primary source provided. The "Year" is the reference year. | Wilkie and Fortuna 2003 |
| Guinea | 1974 | 262000 | | Khalidou Diallo. 1978. La forêt guinnéenne. Etat actuel et perspective d'avenir. Conakry. | 0 | Cited in FAO, UNEP, 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | Wilkie and Fortuna 2003 |
| | | | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 0 | | |
| Guinea | 1980 | 260000 | | | 0 | Updating and estimation for 1980 based on Khalidou Diallo, 1978. (see above) | Wilkie and Fortuna 2003 |
| Guinea | 1985 | 308300 | | Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp. | 0 | Map analysis. Scale 1:700 000. | Wilkie and Fortuna 2003 |
| Guinea | 1987 | 250000 | | Commission of the European Communities. 1987. Mangroves of Africa and Madagascar. Conservation and reclamation: The Mangroves of Madagascar. CML, Centre for Environmental Studies, University of Leyden, 24 pp. | 0 | Secondary reference, no primary source provided. The "Year" is the publication year. Rough estimate. | Wilkie and Fortuna 2003 |
| Guinea | 1960 | 223000 | 60500 | Altenburg, W. 1987. Waterfowl in West African Coastland Wetlands: a summary of current knowledge of the occurence of waterfowl in wetlands from Guinea-Bissau to Cameroon and a bibliography of information sources. Zeist, The Netherlands: Stichting WIWO (Werkgroep International Wad- en Watervogelonderzoek). | | IGN maps from 1950-60 1: 1million and an old map 1: 500.000 for 1940-50. Year is year of IGN map. | Wilkie and Fortuna 2003 |
| | | | | | 0 | | |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| Guinea | 1991 | 156732 | | Calculated from Anonymous 2000 | 0 | calculation: all mangrove-rice, rainfed lowland- and irrigated lowland rice out of total rice area | |
| Guinea | 1993 | 385000 | | Diallo, A. 1993. Mangrove of Guinea. In: Diop, E.S. 1993. Conservation and sustainable utilization of mangrove forests in Latin America and Africa regions, Part II - Africa. p. 47-59. Mangrove Ecosystems Technical Reports vol.3 ITTO/ISME Project PD114/90. Okinawa, Japan, ISME. 262 pp. | 0 | The figure represents the total surface of the mangrove swamp. Secondary reference, no primary source provided. The "Year" is the publication year. | Wilkie and Fortuna 2003 |
| Guinea | 1996 | 316000 | | Iremonger, S., Ravilious, C., and Quinton, T. ,eds. 1997. A global overview of forest conservation CD-ROM. World Conservation Monitoring Centre and Centre for International Forestry Research, Cambridge, U.K. | 0 | Cited in: Forest World. n.d. The Sustainable Forest Products Resource. http://forestworld.com/public/country/countryfra-me.html.The methodology is not specified. Wilkie and Fortuna 2003 | Wilkie and Fortuna 2003 |
| Guinea | 2000 | 290000 | | Aizpuru, M., Achard, F., and Blasco, F. 2000. Global Assessment of Cover Change of the Mangrove Forests using satellite imagery at medium to high resolution. In EEC Research project n 15017-1999-05 FIED ISP FR – Joint Research center, Ispra. | 0 | Secondary reference, no primary source provi-ded. The "Year" is the publication year. It could be a rough estimate based on Saenger and Bellan, 1995. (see above) | Wilkie and Fortuna 2003 |
| Guinea | 2003 | 221499 | 28720 | Bos et al 2006 | 0 | Remote sensing | |
| Guinea | 1950's | 400000 | | Trolliet, B. & Fouquet, M. 2004. Wintering waders in coastal | 0 | | |
| Guinea | 1990? | 250000 | 800 | SECA 1990 in: Trolliet, B. & Fouquet, M. 2004. Wintering waders in coastal Guinea. WSG Bull 103: 56-62. | 0 | | |
| Guinea-Bissau | 1976 | 243000 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 1 | Expert estimate based on SCET International. 1976. République de Guinée-Bissau - Potentialités agricoles, forestières et pastorales. Vol I: Diagnostic sur l'agriculture et les ressources forestières - Esquisse de schéma directeur de développement agricole et forestier. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1978 | 299060 | 180728 | Carte de lóccupation du sol des provinces cotieres 1978, Republica da Guine-Bissau : mapa da vocacao dos solos : fohla ouest et este / Comissariado de estado de agricultura e pecuaria, Comissariado dos recursos naturais, Fonds d'ai-de et de cooperation de la Republique francaise. - [S.l.] (FRA) : SCET-International, 1978 | 1 | estimate based on remote sensing SCET International. 1976. République de Guinée-Bissau | |
| Guinea-Bissau | 1980 | 229000 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 1 | Interpretation of aerial photographs (1:100 000). The document provides the extent of mangroves and palms (235 000 ha), among which 6 000 ha are palms, thus the extent of mangroves is 229 000 ha. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1985 | 287000 | | Atlanta consult 1985 in Diombera 1999 | 1 | | |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| Guinea-Bissau | 1990 | 248400 | | CIRAD-Forêt. 1992. Evaluation des surfaces forestières en Guinée-Bissau. In: Diombera K. 1999. Programme d'évaluation des ressources forestières mondiales au Guinée Bissau. GCP/INT/679/EC. Programme de partenariat CE-FAO (1998-2002). http://www.fao.org/DOCREP/004/X6807F/X6807F00.HTM | 1 | Remote sensing | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1993 | 233798 | 133232 | Cuq, 1996. GUINEA BISSAU reactualisation, de lóccupation du sol au 1:200000, de 1978 estimate based on remote sensing by Geomer | 1 | estimate based on remote sensing by Geomer | |
| Guinea-Bissau | 2002 | 252069 | 53039 | Bos et al 2006 | 1 | Remote sensing | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1940 | 476000 | | Sá, J. 1994 La planification côtière de Guinée-Bissau In: Cormier-Salem, M.-C., ed. 1994. Actes de l'atelier de travail Dynamique et usages de la mangrove dans les pays des rivières du sud (du Sénégal a la Sierra Leone), Dakar, 8 -15 mai 1994. Paris, France. 353 pp. | 0 | The figure reported in this document refers to the "original" extent of mangroves. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1975 | 250000 | | Guinea-Bissau 1975 250000 Hughes, R.H. and Hughes, J.S. 1992. A Directory of African Wetlands. IUCN, Gland, Switzerland and Cambridge, UK/UNEP, Nairobi, Kenya/WCMC, Cambridge, UK. 820 pp | 0 | Analysis of maps and/or remote sensing imageries. No specific scale is given. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1980 | 347000 | | Cormier-Salem, M.C. 1994. Dynamique de espaces littoraux des Rivières du Sud: grands traits de comparaison. In: Cormier-Salem, M.-C., ed. 1994. Actes de l'atelier de travail Dynamique et usages de la mangrove dans les pays des rivières du sud (du Sénégal a la Sierra Leone), Dakar, 8 -15 mai 1994. Paris, France. 353 pp | 0 | Secondary reference, no primary source provided. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1986 | 206250 | | Hughes, R.H. and Hughes, J.S. 1992. A Directory of African Wetlands. IUCN, Gland, Switzerland and Cambridge, UK/UNEP, Nairobi, Kenya/WCMC, Cambridge, UK. 820 pp | 0 | Analysis of maps and/or remote sensing imageries. No specific scale is given. This figure has been elaborated on the basis of the 1975 extent (see above) taking into account a loss of mangroves of approximately 15 percent-20 percent. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1987 | 236000 | | Altenburg, W. 1987. Waterfowl in West African Coastland Wetlands: a summary of current knowledge of the occurence of waterfowl in wetlands from Guinea-Bissau to Cameroon and a bibliography of information sources. Zeist, The Netherlands: Stichting WIWO (Werkgroep International Wad- en Watervogelonderzoek). | 0 | Cited in: Fisher, P and Spalding, M.D. 1993. Protected areas with mangrove habitat. Draft Report World Conservation Centre, Cambridge, UK. 60pp. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1987 | 250000 | | Commission of the European Communities. 1987. Mangroves of Africa and Madagascar. Conservation and reclamation: The Mangroves of Madagascar. CML, Centre for Environmental Studies, University of Leyden, 24 pp. | 0 | Secondary reference, no primary source provided. The "Year" is the publication year | Wilkie and Fortuna 2003 |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| Guinea-Bissau | 1990 | 364900 | | Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp. | 0 | Map analysis. 1:1 000 000. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1994 | 46150 | | Calculated from Anonymous 2000 | 0 | calculation: all mangrove-rice, rainfed lowland- and irrigated lowland rice out of total rice area | |
| Guinea-Bissau | 1996 | 236600 | | WRI, UNEP, UNDP, The World Bank. 1996. World Resources 1996-1997. New York and Oxford University Press 365 pp. | 0 | Secondary reference, no primary source provided. The "Year" is the publication year. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 1996 | 317000 | | Iremonger, S., Ravilious, C., and Quinton, T., eds. 1997. A global overview of forest conservation CD-ROM. World Conservation Monitoring Centre and Centre for International Forestry Research, Cambridge, U.K. | 0 | Cited in: Forest World. nd. The sustainable Forest Products Resource. http://forestworld.com/public/country/countryfra-me.html. The methodology is not specified. | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 2000 | 315000 | | World Resources Institute. 2000. World resources 2000-2001: people and ecosystem—the fraying web of life. Washington, DC., UNDP. 400 pp. | 0 | Secondary reference, no primary source provi-ded. The "Year" is the publication year | Wilkie and Fortuna 2003 |
| Guinea-Bissau | 2000 | 240000 | | Aizpuru, M., Achard, F., and Blasco, F. 2000. Global Assessment of Cover Change of the Mangrove Forests using satellite imagery at medium to high resolution. In EEC Research project n 15017-1999-05 FIED ISP FR – Joint Research center, Ispra. | 0 | Secondary reference, no primary source provi-ded. The "Year" is the publication year. | Wilkie and Fortuna 2003 |
| Senegal | 1978 | 175700 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 1 | Information based on: FAO. 1975. Mise en valeur de la Basse et Moyenne Casamance - Inventaire forestier. Rapport préparé par le centre technique forestier tropical - Project DP/SEN/71/552 - 1/FO -Nogent-sur-Marne (France) and FAO. 1978. Mise en valeur de la Basse et Moyenne Casamance - Inventaire forestier. Rapport final (sylviculture). par R. Lang. DP/SEN/71/552 - 1/FO -Nogent-sur-Marne (France) | Wilkie and Fortuna 2003 |
| Senegal | 1980 | 169000 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs. FAO, UNEP 586pp. | 1 | Estimation based on 1978 information. | Wilkie and Fortuna 2003 |
| Senegal | 1985 | 182400 | | Piot J., Ly A., Gueye I. 1991. Etude sur la gestion des res-sources forestières et des terroirs villageois. Elaboration du Plan d'action forestier du Sénégal. FAO, Rome. | 1 | Ground survey | Wilkie and Fortuna 2003 |
| Senegal | 1985 | 171303 | | Arc Info files of G. Tappan (Stancioff et al.,1986; Tappan et al. 2004) , USAID and US Geological Survey, National Mapping Division, EROS Data Center. 1985. Range and Forest Resources of Senegal. | 1 | Vegetation map scanned and georeferenced, classificatin not suitable for estimating rice this figure refers to the whole country. South of 14 30 0 N 169379 ha or 98.9% is found | |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| Senegal | 2002 | 145224 | 18259 | Bos et al 2006 | 1 | Area south of 14 30 0 N is 1900ha less. Remote sensing. According to maps of Stancioff et al. another 1900 ha above the line 14 30 N in Senegal | Wilkie and Fortuna 2003 |
| Senegal | 1983 | 440000 | | Saenger, P., Hegerl E.J. and J.D.S., Davie. 1983. Global status of mangrove ecosystems. Commission on Ecology Papers No.3. IUCN. Gland, Switzerland. 88 pp. | 0 | Secondary reference, no primary source provided. The "Year" is publication year. | Wilkie and Fortuna 2003 |
| Senegal | 1985 | 183000 | | Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp. | 0 | Map analysis. Scale: 1:1 000 000 | Wilkie and Fortuna 2003 |
| Senegal | 1992 | 75000 | | Calculated from Anonymous 2000 | 0 | calculation: all mangrove-rice, rainfed lowland- and irrigated lowland rice out of total rice area | |
| Senegal | 1993 | 500000 | | Diop, E.S. and Bâ, M. 1993. Mangroves of Sénégal and Gambia. In: Diop, E.S. 1993. Conservation and sustainable utilization of mangrove forests in Latin America and Africa regions, Part II - Africa. p. 19-37. Mangrove Ecosystems Technical Reports vol.3 ITTO/ISME Project PD114/90. Okinawa, Japan, ISME. 262 pp. | 0 | The figure represents the total extent of mangroves in Senegal and Gambia | Wilkie and Fortuna 2003 |
| Senegal | 1995 | 185300 | | Saenger, P. and Bellan, M.F. 1995. The Mangrove vegetation of the Atlantic coast of Africa. Universitè de Toulouse Press, Toulouse 96 pp. | 0 | Secondary reference, no primary source provided. The "Year" is publication year. | Wilkie and Fortuna 2003 |
| Senegal | 2000 | 180000 | | Aizpuru, M., Achard, F., and Blasco, F. 2000. Global Assessment of Cover Change of the Mangrove Forests using satellite imagery at medium to high resolution. In EEC Research project n 15017-1999-05 FIED ISP FR – Joint Research center, Ispra. | 0 | Extrapolation for the national figure based on the remote sensing case study 'The Sine Saloum Coast'. | Wilkie and Fortuna 2003 |
| Sierra Leone | 1976 | 171600 | | FAO. 1979. Land in Sierra Leone: A reconnaissance survey and evaluation for agriculture. Based on the work of Birchall, C.J., Birchall, C.J., Bleeker, P., Cusani-Visconti, C. FAO/LRSP Technical Report No. 1. SIL/73/002 | 1 | Aerial photographs 1975-1976. Scale 1:70 000 | Wilkie and Fortuna 2003 |
| Sierra Leone | 1986 | 156500 | | FAO. 1996. Review of Existing Sources of information for Forest Resource Assesment in Sierra Leone. By Laumans Paul A. Field document. DP/SIL/92/006, Rome, 36 pp. | 1 | Remote sensing. No information on the scale. Wilkie and Fortuna 2003 | Wilkie and Fortuna 2003 |
| Sierra Leone | 2003 | 108480 | 3998 | Bos et al 2006 | 0 | Remote sensing, area north of 7 30 0 N | Wilkie and Fortuna 2003 |
| Sierra Leone | 1976 | 185400 | | FAO. 1996. Review of Existing Sources of information for Forest Resource Assesment in Sierra Leone. By Laumans P. A. Field document. DP/SIL/92/006, Rome, 36 pp. | 0 | Remote sensing. Probably based on analysis of aerial photographs 1975-1976. | Wilkie and Fortuna 2003 |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| Sierra Leone | 1976 | 283761 | | FAO. 1979. Land resources survey, Sierra Leone. AG:DP/SIL/73/002 Field Document 1. Sierra Leone Freetown. | 0 | Cited in: Johnson, R. and R. Johnson. 1993. Mangroves of Sierra Leone. In: Diop, E.S. 1993. Conservation and sustainable utilization of mangrove forests in Latin America and Africa regions, Part II - Africa. pp: 7-9. . Mangrove Ecosystems Technical Reports vol.3 ITTO/ISME Project PD114/90. Okinawa, Japan, ISME. 262 pp. The figure might include also freshwater swamps. | Wilkie and Fortuna 2003 |
| Sierra Leone | 1983 | 100000 | | Saenger, P., Hegerl E.J. and J.D.S., Davie. 1983. Global status of mangrove ecosystems. Commission on Ecology Papers No.3. IUCN. Gland, Switzerland. 88 pp. | 0 | Secondary reference, no primary source provided. The "Year" is publication year. | Wilkie and Fortuna 2003 |
| Sierra Leone | 1987 | 250000 | | Altenburg, W. 1987. Waterfowl in West African Coastland Wetlands: a summary of current knowledge of the occurence of waterfowl in wetlands from Guinea-Bissau to Cameroon and a bibliography of information sources. Zeist, The Netherlands: Stichting WIWO (Werkgroep International Wad-en Watervogelonderzoek). | 0 | Cited in: Fisher, P and Spalding, M.D. 1993. Protected areas with mangrove habitat. Draft Report World Conservation Centre, Cambridge, UK. 60pp. | Wilkie and Fortuna 2003 |
| Sierra Leone | 1991 | 286000 | | FAO. 1991. Alleviation of the Fuelwood Supply Shortage in the Western Area - Sierra Leone. FO:DP/SIL/84/003 FO:DP/SIL/88/008 Terminal Report | 0 | The figure represents the extent of coastal woodland-mangrove and swamps. It may include freshwater swamps. | Wilkie and Fortuna 2003 |
| Sierra Leone | 1993 | 113920 | | Calculated from Anonymous 2000 | 0 | calculation: all mangrove-rice, rainfed lowland- and irrigated lowland rice out of total rice area | |
| Sierra Leone | 1995 | 183800 | | Saenger, P. and Bellan, M.F. 1995. The Mangrove vegetation of the Atlantic coast of Africa. Universitè de Toulouse Press, Toulouse 96 pp | 0 | Secondary reference, no primary source provided. "Year" is the publication year. | Wilkie and Fortuna 2003 |
| Sierra Leone | 1997 | 169500 | | Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp. | 0 | Map analysis. The map was undated. | Wilkie and Fortuna 2003 |
| The Gambia | 1968 | 66500 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 1 | Interpretation of aerial photos dated 1968 | Wilkie and Fortuna 2003 |
| The Gambia | 1978 | 175700 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 1 | Information based on: FAO. 1975. Mise en valeur de la Basse et Moyenne Casamance - Inventaire forestier. Rapport préparé par le centre technique forestier tropical - Project DP/SEN/71/552 - 1/FO -Nogent-sur-Marne (France) and FAO. 1978. Mise en valeur de la Basse et Moyenne Casamance - Inventaire forestier. Rapport final (sylviculture). par R. Lang. DP/SEN/71/552 - 1/FO -Nogent-sur-Marne (France) | Wilkie and Fortuna 2003 |
| | 1980 | 68000 | omvg | | | | |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| The Gambia | 1980 | 169000 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs. FAO, UNEP 586pp. | 1 | Estimation based on 1978 information. | Wilkie and Fortuna 2003 |
| The Gambia | 1982<br>1983 | 68000<br>56000 | | Ludwig.R and Bojang.L. 1998. Results and Analysis of the National Forest Resources Inventory The Gambia 1997/98 | 1 | Interpretation of aerial photos. | Wilkie and Fortuna 2003 |
| The Gambia | 1985 | 182400 | | Piot J., Ly A., Gueye I. 1991. Etude sur la gestion des ressources forestières et des terroirs villageois. Elaboration du Plan d'action forestier du Sénégal. FAO, Rome. | 1 | Ground survey | Wilkie and Fortuna 2003 |
| The Gambia | 1985 | 58603 | | Arc Info files of G. Tappan (Stancioff et al.,1986; Tappan et al. 2004) , USAID and US Geological Survey, National Mapping Division, EROS Data Center. 1985. Range and Forest Resources of Senegal. | 1 | Remote sensing, see ref in Iremonger et al 1997. Same primary source! | |
| The Gambia | 1993 | 59600 | | Ludwig.R. and Bojang.L. 1998. Results and Analysis of the National Forest Resources Inventory The Gambia 1997/98 | 1 | Interpretation of aerial photos and ground survey. | Wilkie and Fortuna 2003 |
| The Gambia | 2001 | 65464 | 22687 | JICA, courtesy of NEA | 1 | Interpretation of aerial photos. topographical map | |
| The Gambia | 2002 | 67943 | 8800 | Bos et al 2006 | 1 | Remote sensing | Wilkie and Fortuna 2003 |
| The Gambia | 1971 | 64000 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 0 | Interpretation of aerial photos dated 1968 and updating. | Wilkie and Fortuna 2003 |
| The Gambia | 1980 | 60000 | | FAO, UNEP. 1981. Tropical Forest Resources Assessment Project, Forest Resources of Tropical Africa. Part II: Country Briefs FAO, UNEP 586pp. | 0 | Estimation for the end of 1980. Rough estimate. Wilkie and Fortuna 2003 | Wilkie and Fortuna 2003 |
| The Gambia | 1982 | 74850 | 11353 | Tyldum unpublished. Geographic Information System (GIS) files which show the landuse and vegetation classifications of The Gambia. This data was digitized by Geir Tyldum (geir.tyldum@statkart.no, http://www.geocities.com/TheTropics/Shores/9551/info4.htm) from maps made in 1982 by the Office of Remote Sensing, South Dakota State University, USA. The data is in ESRI shapfile format. | 0 | Remote sensing | |
| The Gambia | 1983 | 440000 | | Saenger, P., Hegerl E.J. and J.D.S., Davie. 1983. Global status of mangrove ecosystems. Commission on Ecology Papers No.3. IUCN. Gland, Switzerland. 88 pp. | 0 | Secondary reference, no primary source provided. The "Year" is publication year. | Wilkie and Fortuna 2003 |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| The Gambia | 1985 | 51300 | | USAID and US Geological Survey, National Mapping Division, EROS Data Center. 1985. Range and Forest Resources of Senegal. | 0 | Iremonger, S., C. Ravilious and T. Quinton. 1997. A statistical analysis of global forest conservation. In: Iremonger, S., C. Ravilious and T. Quinton. eds. A global overview of forest conservation. Including: GIS files of forests and protected areas, version 2. CD-ROM. CIFOR and WCMC, Cambridge, U.K. http://www.unep-wcmc.org/forest/data/cdrom2/index.html | Wilkie and Fortuna 2003 |
| The Gambia | 1985 | 74700 | | Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp. | 0 | Map analysis. Scale 1:1 000 000. According to the authors, the estimate provided by Saenger and Bellan, 1995 (see below) is likely to be more accurate. | Wilkie and Fortuna 2003 |
| The Gambia | 1985 | 183000 | | Spalding, M.D., Blasco, F. and Field, C.D., eds. 1997. World Mangrove Atlas. The International Society for Mangrove Ecosystems, Okinawa, Japan. 178 pp. | 0 | Map analysis. Scale: 1:1 000 000 | Wilkie and Fortuna 2003 |
| The Gambia | 1987 | 66000 | | Altenburg, W. 1987. Waterfowl in West African Coastland Wetlands: a summary of current knowledge of the occurence of waterfowl in wetlands from Guinea-Bissau to Cameroon and a bibliography of information sources. Zeist, The Netherlands: Stichting WIWO (Werkgroep International Wad- en Watervogelonderzoek). | 0 | Cited in: Fisher, P and Spalding, M.D. 1993. Protected areas with mangrove habitat. Draft Report World Conservation Centre, Cambridge, UK. 60pp. Secondary reference, no primary source provided. "Year" is the publication year. | Wilkie and Fortuna 2003 |
| The Gambia | 1988 | 16150 | | Calculated from Anonymous 2000 | 0 | calculation: all mangrove-rice, rainfed lowland- and irrigated lowland rice out of total rice area | |
| The Gambia | 1992 | 45000 | | Hughes, R.H. and Hughes, J.S. 1992. A Directory of African Wetlands. IUCN, Gland, Switzerland and Cambridge, UK/UNEP, Nairobi, Kenya/WCMC, Cambridge, UK. 820 pp. | 0 | Analysis of maps and/or remote sensing imageries. No specific scale is given. "Year" is the publication year. | Wilkie and Fortuna 2003 |
| The Gambia | 1993 | 500000 | | Diop, E.S. and Bâ, M. 1993. Mangroves of Sénégal and Gambia. In: Diop, E.S. 1993. Conservation and sustainable utilization of mangrove forests in Latin America and Africa regions, Part II - Africa. p. 19-37. Mangrove Ecosystems Technical Reports vol.3 ITTO/ISME Project PD114/90. Okinawa, Japan, ISME. 262 pp. | 0 | The figure represents the total extent of mangroves in Senegal and Gambia Wilkie and Fortuna 2003 | Wilkie and Fortuna 2003 |
| The Gambia | 1994 | 67000 | | FAO. 1994. Integrated Coastal Fisheries Management in the Gambia By: Willmann, R. FI:DP/INT/91/007 Pilot project of INT/91/007 | 0 | Secondary reference, no primary source provided. "Year" is the publication year. Estimation. | Wilkie and Fortuna 2003 |
| The Gambia | 1995 | 49700 | | Saenger, P. and Bellan, M.F. 1995. The Mangrove vegetation of the Atlantic coast of Africa. Universitè de Toulouse Press, Toulouse 96 pp. | 0 | Secondary reference, no primary source provided. "Year" is the publication year. | Wilkie and Fortuna 2003 |

| Country | Year | Mangrove Area (ha) | Rice area (ha) | Source | Mangrove Trend | Methodology/Comments | cited from |
|---|---|---|---|---|---|---|---|
| The Gambia | 1995 | 185300 | | Saenger, P. and Bellan, M.F. 1995. The Mangrove vegetation of the Atlantic coast of Africa. Universitè de Toulouse Press, Toulouse 96 pp. | 0 | Secondary reference, no primary source provi-ded. The "Year" is publication year. | Wilkie and Fortuna 2003 |
| The Gambia | 1999 | | | Sogreah Ingenerie 1999 0 1500 ha currently under irrigation, 15.300 ha is tidal swamp= potential rice area | 0 | 1500 ha currently under irrigation, 15.300 ha is tidal swamp= potential rice area | Verkerk & Rens 2005 |
| The Gambia | 2000 | 180000 | | Aizpuru, M., Achard, F., and Blasco, F. 2000. Global Assessment of Cover Change of the Mangrove Forests using satellite imagery at medium to high resolution. In EEC Research project n 15017-1999-05 FIED ISP FR – Joint Research center, Ispra. | 0 | Extrapolation for the national figure based on the remote sensing case study 'The Sine Saloum Coast'. | Wilkie and Fortuna 2003 |