

## **WANSEC: Sub-project A: Bush fires in West Africa**

### **Background**

Bush fires play an integral role in the savannah ecosystems of semi-arid and sub-humid West Africa (Goldammer, 1997). It is generally agreed that fires have accompanied the evolution of terrestrial plants (Andreae, 1991) and that bush fires have been shaping the African savannah ecosystem since their emergence in the tertiary period approximately 65 million years ago. Whereas these prehistoric fires had natural causes, the ascendance of humans with their ability to master and apply fire as a tool or weapon introduced new causes for environmental fires. Ultimately, humans became the single most important agent for the occurrence of fire (Langaas, 1995). Human use of fire has certainly increased the frequency of fire but it is also likely to have changed the spatial as well as temporal distribution of fires.

In most West African countries, savannah fires are a controversial subject; they are often indiscriminately labelled a harmful and hazardous phenomenon. This point of view was often adopted by colonial administrators and can still be encountered in present day West Africa. Gradually this perception is changing, and in certain areas fires are increasingly considered a rational element in natural resource management. This reflects the practices of cultivators, pastoralists, forestry agents and national park administrators who use fire as a tool. While fires may serve rational purposes, they also have harmful effects, and what may constitute a positive outcome at one scale may be considered negative at another. Irrespective of scale, a better understanding of the spatial and temporal distribution of fires, as well as their causes, is necessary for the development of an appropriate management policy (Mbow et al., 2000).

Bush fires have been listed among the strongest factors of savannah dynamics particularly with respect to assessment of structural and qualitative diversity of the savannah ecosystem. Fire influences the shape and functioning of vegetation types, soil erosion, hydrological processes and overall ecosystem stability (Schmitz et al. 1996; Brookman-Amissah et al., 1980; Louppe et al., 1995). The ecological consequences imply several long term drawbacks in rural economy, even when short time or instant benefits underpins most of savannah burning. Rural activities are associated with burning in Africa for a wide range of management systems including herbs regrowth promotion, acquisition of new lands, land clearing, field preparation, reduction of bush encroachment, prevention of late destructive fires, etc. (Mbow et al. 2000; West, 1965). It becomes therefore important for managers to be provided with spatial and temporal real time data for a better assessment of the fire events in a given area.

Because of the prevalence of fires in savannah, burning has been flagged by ecologists as part of ecosystem processes. Therefore, previous studies do not recommend an integral protection against fires, which is considered as a “dangerous utopia” (Louppe et al., 1995) because it is extremely challenging and very risky to systematically ban fire in savannah conditions. Moreover, survey made in permanent plots by Aubreville at Lampto in Côte d’Ivoire (Louppe et al. 1995), by Brookman-Ammissah (1980) in Ghana and Sonko (2000) working in Niokolo Koba National Park in Senegal showed that fire impacts in savannah vegetation is more related to fire intensity than the mere

presence of annual burning. These results make it plausible that the use of early burning can be a balanced option between drastic late fires and risky total protection of ecosystems.

The majority of fire studies have been conducted using data from the NOAA AVHRR satellite sensor. Data from this sensor allows for the detection of fires that are actually burning during image acquisition. Data is acquired two times per day; respectively night and afternoon. While night time images have been employed in fire monitoring studies (Langaas, 1995), the vast majority of studies of fire distribution have been based on day time AVHRR images. Two separate approaches in fire detection can be identified. The first approach, and the approach that constitutes the vast majority of fire studies, is based on the detection of actively burning fires during image acquisition. This approach has been used on all continents and has proven a solid and reliable source of information on fire distribution. However, several methodological problems and shortcomings of this approach can be identified and the interpretation of fire distribution maps based on active fires can vary (Eva & Lambin, 1998).

Even very small fires may be detected by the active fire approach, if they are burning with enough heat. This entails that the results produced based on this approach may be overestimating the smaller fires, while larger fires, burning less intense may be left largely undetected. Also, it is important to note that even though a fire can affect a very large area, only the part of the fire actively burning during image acquisition is detected. Active fire detection is also hampered by clouds and since many fires in West Africa occur shortly following the rainy season, this can lead to underestimation of fires using the active fire approach (Eva & Lambin, 1998a; Mbow et al. 2000; Nielsen et al. 2002)

The other approach to fire monitoring is to detect the burned, charred surfaces left behind by a fire occurrence. This approach is generally known as the burned area approach, or fire scar approach. As with the active fire maps, also distribution maps based on the burned area approach have to be interpreted with some caution. First of all, only relatively large fires are actually detected using this approach. This is in contrast to the active fire approach where even very small fires can be detected if they are hot enough. Secondly, fire scar detection algorithms are mostly depending on analyses of temporal profiles at pixel level. For a given pixel the spectral response or a vegetation index or other parameter can be analysed and if and when this parameter suddenly decreases, the pixel is marked as a fire scar. However, this leaves the fire scar approach highly vulnerable to quality issues of coregistration of images as even a small shift in pixel location can yield many misregistrations. Also, this analysis requires that individual images and pixels are analysed on a background. Due to rapid changes in the atmospheric conditions, it is difficult to establish a solid background to perform this analysis. Therefore, temporal composite data has been used as a background for analysis of burned areas.

Still, the fire scar approach holds several advantages over the active fire approach and much work involving several satellite sensor platforms has been performed in order to establish globally applicable algorithms that will detect burned areas. Eva & Lambin (1998b) worked in central Africa using ATSR data, while Barbosa et al. (1998) employed data from the AVHRR sensor at continental level. At the regional and

national level Fuller and Fulk (2001) employed data from the AVHRR sensor for studies of fires in Kalimantan, while Nielsen et al. (2002) used AVHRR data to study fire scars in and around a national park in South East Senegal. Other data sources have also been employed: Strompiana et al (2002, 2003) used data from the SPOT VEGETATION while Martin et al. (2002) and Roy et al. (2002, 2005) and many others employed data from the MODIS sensor.

However, as reported by several authors (i.e. Eva & Lambin, 1998a; Nielsen & Rasmussen, 2001) globally applicable algorithms to detect either actively burning fires or fire scars may not provide optimum accuracy for national and local studies. Issues as discussed above, such as geo-referencing of pixel, atmospheric conditions etc. all affect the result of the fire detection. Hence, there is need to adopt and adjust the algorithms to suit local conditions. The need to provide locally correct information on fire occurrence in time and space becomes even more pressing when the outputs from remote sensing techniques are used as input into analyses of fire regimes.

The general concept of a fire regime is usually defined in terms of spatial and temporal statistical properties combined with a measure of intensity (Goldammer, 1993; Dwyer et al. 1998; Frost & Robertson, 1985; Christensen, 1993; Miittinen, 2007). Currently, no strict definition of term is agreed upon and the exact components of a fire regime description vary with the orientation of studies. Goldammer (1993) operates with seven distinct global fire regimes based on the return interval of fire. These in turn each relate to ecological and anthropogenic gradients such as population density, grazing pressure, landscape heterogeneity, erosion and species composition and diversity. In Dwyer et al. (1998) five fire regimes are identified with varying fire frequency, spatial intensity and burning season length. Other parameters, such as topology, post fire changes in ecosystem structure of land use and determinants of interactions between humans, fire and ecosystems (Kaufmann et al. 1993).

In general terms, the description of a particular fire regime, or fire regimes of a region, should include parameters which are essential to understand respectively: The characteristics of a given fire regime, the determinants and the impacts of a fire regime.

Fire regime characteristics should be separated from the determinants as well as the impacts of the fire regime and should include parameters describing the spatial and temporal distribution of fires as well as physical and statistical characteristics of that fire regime. Whereas several parameters could be included in a list of fire regime characteristics, no final list can be produced since the exact composition of any list will vary with the topic of any study (Nielsen & Rasmussen, 1997).

The determinants of a fire regime are the physical, social and economic framework in which the fire occurs. It can include parameters such as ecosystem properties, above ground biomass available for combustion, precipitation, population density, natural resource management practices and legislation (Mbow et al. 2000). Whereas the parameters of the fire regime characteristics are mostly measurable, some of the parameters constituting the determinants are not, and evidence of causality between determinants and characteristics will often be of a circumstantial nature.

The environmental impacts of a given fire regime is the physical, biological and economical impact, or cost, that can be observed or measured in the surrounding environment. This could include release of greenhouse gasses to the atmosphere, depletion of woody biomass, impacts on soil micro biological productivity as well as species composition and loss of biodiversity and other environmental parameters of particular interest.

Thus, the occurrence of fires and the spatial and temporal distribution of fires is a phenomenon which cannot be explained or understood merely by with reference to the physical, social or economic framework surrounding the fire occurrence. Rather, the wide spread occurrence of fire on the West African savannas must be seen as the result of a complex relationship of physical, social and economic inter-relationship.

On this background, this subproject aims at:

### **Objectives**

- To develop capacity among the partner institutions to use satellite remote sensing data and contemporary analysis methods to identify and monitor savanna vegetation fires.
- To study the extent and spatial and temporal distribution of bush fires in order to contribute to the knowledge of fire regimes
- To study the impacts of fires across the region, and to provide insight into the role of bush fires in the release of greenhouse gases and climate change.
- To study and develop new methods of bush fire detection and monitoring based on new satellite sensor platforms. This will include both the option of detection active fires and the detection of burned areas.

### **Sub-project activities**

- To establish central processing capabilities for the processing, production and distribution of daily fire distribution maps. The WANSEC internet site will be used to distribute data amongst project partners.
- To develop a Ph.D. and staff training course on fire monitoring and fire risk assessment methods for subsequent interpretation of results obtained from satellite image.
- To perform research into the application of new data sources into fire monitoring and to suggest applicable methods and technologies for all partner institutions.
- To develop a common data and field work protocol usable by all project partners. This protocol will be applied through field work campaigns in all sub-project partner countries.

### **Participating institutions**

- All partner institutions will partake in this sub-project.

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## Sub-project B: Climate change and rural land use change

### Background

Land use information over large areas is increasingly important for many studies related to environment in general and change in particular.

Climate and land use/cover change are closely interrelated issues:

- Up to 25 % of the increase in CO<sub>2</sub>-concentration in the atmosphere since the pre-industrial period is caused by changes in land use/cover, and deforestation in particular.
- The climate change forecasted for the next century will, in itself, have considerable effects on land use/cover, and changes at the global scale can already be detected. However, the climate change projections for West Africa are still very uncertain, especially as concerns changes in rainfall (Christensen *et al.*, 2007)
- Land use, and thus land cover, may be changed as an active adaptation to climate change. This is obvious both at the global scale and in West Africa.
- Land use may affect groundwater (quantity and quality) and surface water productivity in watershed.
- Land use may change in the future due to the mitigation actions associated with the implementation of the Kyoto Protocol. So-called CDM-projects, aiming at decreasing net CO<sub>2</sub>-emissions, may include afforestation-activities (Touré *et al.*, 2003)( Elberling *et al.*, 2003).
- The switch from fossil fuels to CO<sub>2</sub>-neutral energy sources, driven by climate concerns, will imply increased demand for (and prices on) renewable energy, likely to lead to changes in land use towards production of vegetable oils and/or biomass forming the basis of ethanol-production.

Obviously, rural land use/cover may change for a range of other reasons, including population growth, changes in domestic and international demand for agricultural products and changes in international trade arrangements. Separating land use/cover changes associated with climate change mitigation and adaptation from changes due to other factors is far from simple.

Land use/cover is also a major component in land degradation processes in West Africa. It has been widely claimed that inappropriate land use, both crop production on unsuitable lands, overgrazing and excessive cutting of woody vegetation for fuel wood and/or timber, is causing land degradation (Geist & Lambin, 2004). However, the picture of a continuous, ongoing land degradation in West Africa is challenged by a number of studies showing increases in 'greenness' (Eklundh & Olsson, 2003) (Anyamba & Tucker, 2005) (Herrmann *et al.*, 2005) (Olsson *et al.*, 2005) (Hickler *et al.*, 2005) or constant/increasing 'rain use efficiency' (Prince *et al.*, 1998) (Prince *et al.*, 2007) over the last 25 years, based on analysis of time-series of coarse resolution satellite data. In parallel, local scale studies have showed regeneration of the vegetation cover, yet pointed to different explanations (Rasmussen *et al.*, 2001)( Reij *et al.*, 2005)

Finally, land use/cover plays a significant, yet not fully understood, role in the hydrological cycle: Major changes in forest cover are likely to have significant effects on river discharge in the large river basins in West Africa, and expansion of irrigated agriculture has well-documented impacts on river discharge in the Senegal, Volta and Niger basins (UNEP, 2004).

Thus, land use/cover change plays a central role in understanding environmental (including climate) change in West Africa, and it is also closely related to the development of key productive sectors, such as crop and livestock production and forestry. Identification and understanding land use/cover change is therefore crucial.

### *Objectives of the sub-project*

The sub-project aims at:

- Developing capacity among the partner institutions to use Earth Observation data to identify and monitor land use/cover change.
- Identification and explanation of land use/cover changes in the margin of the cropping zone of the Sahel-Sudan, including the extent to which these changes are climate change related.
- Studying the effect of land use/cover change on the storage of Carbon in vegetation, thereby allowing an assessment of the contribution of land use/cover change to GHG emissions, as well as to assess the potential for 'green CDM projects' in the region.
- Identification of land use change related to bio-energy production, both for local and domestic uses and for export. Bio-energy production includes both the traditional extraction of fuel wood for local and urban consumption, the traditional production of charcoal, production of oil-products for replacement of diesel-fuels locally and possible future cultivation of biomass for the purpose of ethanol production for the world market.
- Improved understanding of the relationship between land degradation /regeneration, as indicated by changes in vegetation productivity, land use/cover and other factors.

### *Sub-project activities*

Organized according to the objectives listed above, the following activities are envisaged:

1. PhD-courses/workshops on Earth Observation techniques and field work methodologies.
2. Case study on the cropland/rangeland frontier (or transition zone) and its dynamics in Senegal, Mali, Burkina Faso and Niger. The study will combine analysis of coarse, medium and high spatial resolution data and field work to identify development trends over the last 25 years, and attempt to identify causes of the trends observed, including climate change, population growth and migration trends as well as effects of land degradation and/or improved land management.

3. Case study of the use of land use/cover data from satellite images to assess the impacts of historical land use changes over the last 25 years on Carbon storage in vegetation and soils in Senegal.
4. Case study (with emphasis on Mali) of the changes in land use and vegetation cover expected to result from the increased demand for biomass for bio-energy uses. While the focus in the Sahel has until this day mainly been on the 'fuel wood crisis', that is the overuse of woody vegetation resources caused by increasing local and urban demand, the external and domestic demand for bio-fuels (both oil products replacing diesel and ethanol replacing gasoline) is expected to impact on land use in West Africa in the future. The early identification and mapping of such impacts is essential in order to avoid negative impacts on food production, unsustainable use of water resources and loss of biological diversity.
5. Case study (with emphasis on Niger) of land use/cover change and its relation to land degradation and regeneration, as indicated by changes in vegetation productivity derived from time series of satellite images, particularly NOAA AVHRR. As mentioned above, large parts of the Sahel have experienced a partly recovery of vegetation productivity over the period 1982 to date, and the study will attempt to relate this regeneration to land use/cover as well as to other biophysical and human factors

The four case-studies outlined above will all employ a nested, hierarchical approach in terms of spatial scale: They will seek to bridge the gap between the continental-scale analyses, made possible by coarse resolution data sets based on NOAA AVHRR data from the period 1982-2007, use of medium-to-high resolution satellite data from Landsat TM, ASTER, IKONOS and other sources, and field observation and *in situ* interviews with farmers and pastoralists, thereby resolving some of the inconsistencies apparent in the literature on land degradation in the Sahel.

#### *Participating institutions*

All seven partners plan to take part in the sub-project. As indicated above, a series of case studies will be carried out in the partner countries, and in each case the national partners will play a major role. By involving participants from the other participating universities, a research cross-fertilization is expected to take place.

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## **Sub-project C: Urban and peri-urban land use dynamics**

### **Background**

Most developing countries are known to be urbanizing very fast and in sub-Saharan African countries this is particularly the case with their primate cities and other large urban centres. Within the urban built environment open spaces are being filled in through new physical development, densification of already built-up area, the growth of informal settlements particularly on marginal and ecologically sensitive areas. But perhaps the most noticeable feature of the rapid urbanisation is the rapid urban expansion into the rural surrounding rural areas and in the process creating broad urban-rural transition zones varying in size and extent surrounding the cities. The urban-rural interface has also been altered from a combination of such factors as technological change, global economic restructuring and the impact of externally driven macro-economic adjustment policies (Simon et al, 2006). The peri-urban areas present contrasting land use features such as rapid conversion of agricultural land to a variety of urban land uses, particularly housing, in some parts or zones, while in other areas, particularly areas that are less directly affected by urbanisation there are opportunities for agricultural intensification and commercialisation. The intensity of natural resource extraction for urban uses as well as acting as sinks for waste generated from the cities have resulted in severe environmental degradation of peri-urban areas. This has posed several challenges and in some instances opportunities to the livelihoods of residents of peri-urban areas. This is more so with respect to urban and peri-urban agriculture and food security, particularly in the case of countries in sub-Saharan Africa (see e.g. Brook and Davila, 2000, Memon and Lee-smith, 1993, Freeman, 1991, Maxwell et al, 1999, Briggs and Mwamfupe, 1999, 2000).

As an example of rapid urbanisation and its consequent land conversion and the related environmental impact is Accra, the capital city of Ghana. Accra has been experiencing a rapid rate of growth and it is one of the fastest growing cities in West Africa. According to the results of the 2000 population and housing census of Ghana, the population of the Accra Metropolitan Area, the main urbanised area in Ghana, grew at 4 % per annum between 1984 and 2000 as against a national population growth of about 2.6 % per annum. The population figure of the central city alone of about 1.7 million in 2000 is now well over 2 million. The rapid growth of Accra and the other main cities is also reflected in the rapid conversion of agricultural land to various forms of urban uses. A study based on satellite images shows that the fringe areas of Accra are being urbanized at a pace that has increased from 10 km<sup>2</sup> per year for the period 1985-1991 to 25 km<sup>2</sup> per year for the period 1991-2002 (Yankson et al. 2005). The effects of this have been most marked on urban and peri-urban agriculture not only in and around Accra but also in and around Kumasi, the second city of Ghana (Yankson and Gough, 1999; Gough and Yankson, 2000; Maxwell et al 1999; Kasanga et al, 1996; Edmundson, 1996). The environmental impact of the rapid urbanisation of the peri-urban areas of Accra has been documented (Yankson and Gough, 1999).

With a small population of about 100,000 inhabitants at independence, the political and economic capital of Mali, Bamako, grew very fast from the 1970s to a little over one million inhabitants in 1998. Currently, the city is rapidly expanding into its surrounding rural lands in a haphazard, uncoordinated manner.

The growth of the urban areas in sub-Saharan Africa and in many other developing countries has occurred rapidly and in many instances without any consistent and coordinated planning. Several constraints to planning and management of the metropolitan areas are well known; Some major ones are ineffective enforcement of development controls partly due to lack of funding for the local government, shortage of manpower in planning outfits of local government units; lack of coordination of plans and programmes of development agencies and land litigation problems (Rakodi, 1997).

Investigations into the environmental impact of the rapid and haphazard urban growth experienced by most developing countries are important. As pressure for urban development intensifies, agricultural land in the fringe zone is converted into residential, industrial and other non-agricultural land uses which may create food security problems. Moreover, urban encroachment into forest land around cities has resulted in serious degradation of vegetation cover and loss of biodiversity. As the cities expand into the fringe areas in a largely unplanned and uncontrolled manner, sprawling low-density development is created that is uneconomic in the use of land. The development is haphazard and the new areas lack infrastructural facilities and services like water supply and sanitation. Water, electricity, roads, and other facilities may reach such areas long after the settlements or communities have been built up. In some instances, extending these facilities becomes impossible or very expensive because areas reserved for such purposes have been completely taken over by developers. Planning and development control measures have been inadequate or ineffective in containing such developments.

Climate change is likely to have significant impacts on urban development and environments: In Dakar, low-lying inter-dunal depressions have become foci of expansion of housing for the poor, yet these areas are prone to flooding as the sea level rises or extreme rainfall events become more frequent. On the other hand, drought may cause collapse of urban water supplies and electrical power shortages, due to reduced hydropower production. Thus it becomes increasingly important to 'climate-proof' urban development.

Several studies have shown that medium-resolution satellite images are potentially useful for remote sensing-based growth monitoring and classification of urban land cover on a generalized level, provided classification methods adopted are targeted towards urban areas. In the case of Accra, the magnitude of growth has been documented using medium-scale satellite images in the lack of updated maps. More detailed satellite images have recently become available. These data sources may prove to be very suitable for more detailed extraction of spatial information that will benefit the planning process.

### **Objectives of the sub-project**

- To develop capacity among the partner institutions to use medium and high-resolution satellite images, geographical information systems and other relevant digital techniques to identify and monitor magnitude and direction of urban growth and change.

- To monitor and analyse the recent trends in urban spatial development with focus on the haphazard nature of the spatial development, the possible negative impacts of climate change and the environmental consequences of the lack of planning and the poor land management.
- To carry out a comparative study of Accra in the coastal zone and Bamako in the sudano-Sahelian zone.
- To support the local planning authorities and evaluate the possibility for disseminating important spatial information using internet-based geographic information systems.

The urban growth pattern is assessed in terms of land, population and direction of change using medium and high-resolution satellite images. The growth areas are categorized with respect to densities, buildings types, infrastructure and general service provision. Methods for modelling the urban growth are analysed within the context of overall development, resource distribution and management plans.

### **Sub-project activities**

- Joint research, focusing on selected study sites in all four partner countries. The research methods include satellite image analysis of urban land-use/ land-cover change using medium and high resolution data sources, backed by field work as well as geo-spatial modelling and analysis techniques.
- PhD-courses/workshops on Earth Observation and GIS-based techniques and field work methodologies.
- Application of Remote sensing and GIS-based analysis methods to the process of planning for the provision of social and environmental services in peri-urban areas, including strategies for local planning applications and dissemination of spatial information to relevant user groups.
- Assessing land use/ land cover dynamics on urban and peri-urban agriculture using remote sensing and GIS.
- Spatial risk modelling of urban environmental hazards using remote sensing and GIS, both in the fringe areas and inner cities.

### **Participating institutions**

The partners participating in this sub-project are: University of Dakar, Senegal, University of Ghana, University of Bamako, Mali in collaboration with the University of Copenhagen, Denmark.

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## Sub-project D: Earth Observation of water resources

### Background

The great sensitivity of the economies and environment of West Africa to climate change is to a considerable extent associated with changes in rainfall and the consequent changes in the availability of water resources. More specifically, climate change impacts on water resources may imply the following:

- Changes in crop water availability in rain-fed agriculture, causing changes in crop yields and the optimal choice of failure.
- Changes in plant water availability in the rangelands, causing variations in productivity of the livestock sector.
- Changes in river discharge, causing either flooding/drying out of river valleys, lack of water for irrigation or potential for expansion of irrigation, changes in composition and productivity of important ecosystems in the river valleys, changes in occurrence of water born diseases and changes in hydro-power potential.
- Changes in the availability of ground water resources, including the recharge of large aquifers and base flow which feeds the rivers in dry season.

The likely future direction of change in rainfall is still uncertain in the Sahel-Sudan. The Fourth Assessment Report of IPCC (IPCC, 2007) states that model predictions are inconclusive. It seems, however, the models agree that Senegal is likely to experience a further reduction of rainfall, while other parts of the Sahel-Sudan are more likely to experience an increase. Given the extreme importance of limited water resources in the region, it is highly appropriate to develop capacities for monitoring elements of the hydrological cycle (rainfall, Evapo-Transpiration etc) and understanding the processes influencing it. The hydrological measurement network of West Africa leaves much to be desired, and this is particularly true for the Sahel-Sudan zone. Due to the extreme spatial variability of rainfall, conventional networks can not provide the spatial density of measurements required to support neither analysis of crop and vegetation productivity nor inputs to distributed hydrological models, and thus Earth Observation techniques are highly appropriate.

### Objective and approach

The overall objective of WANSEC's sub-project within Earth Observation of water resources is the development of expertise, in the partner countries as well as in Denmark, on the use of Earth Observation in the study of the hydrology of the West Africa, and the Sahel-Sudan zone specifically, and the availability of water resources.

To achieve this overall goal, several steps will be taken:

- Equipment for analysis of Earth Observation data will be established or upgraded, and the appropriate software acquired.
- Training of staff and PhD-students must be done, taking advantage of the expertise available within the network. This will be organized in the form of PhD-courses and workshops
- Joint research activities, involving both satellite images analysis and field work, will be organized. The field work sites will include catchments already being studied as part of the AMMA EU project.

## Research

The research will, in its initial stages, focus on improved, spatially distributed, estimation of a few key-variables, including:

- Soil surface and air temperature.
- Vegetation/crop water stress and Primary Production modelling.

Land surface temperature and near surface air temperature are key environmental variables in a wide range of applications within ecology, hydrology as well as climate sciences. Sensors like the Advanced Very High Resolution Radiometer (AVHRR) and the Moderate resolution radiometer (MODIS) have provided estimates of surface temperature for the past decades with a spatial resolution of 1000 m and daily overpasses.

The derivation of near surface air temperature from satellites is far from straight forward as compared to the estimation of surface temperature for which general split window techniques have been used extensively since the launch of the NOAA-AVHRR (Prince et al., 1998). The difference between surface temperature and the actual air temperature is mainly controlled by the surface energy balance, which is a complex system dependant on information not usually available from satellites (e.g. wind speed, soil moisture and surface roughness).

The approach pursued in this proposal is the TVX, TVDI and TVWI method (Temperature/Vegetation index, temperature-vegetation dryness index and Temperature/Vegetation Wetness Index Method) (Prince et al., 1998; Goward et al., 2002; Wang et al., 2004; Quazi et al., 2007), circumventing the under-parameterization by its contextual form, which implies that the spatial resolution is traded for increased dimensionality in the measurements. The algorithm uses data from an array of pixels (window) to derive a single estimate, in contrast to most remote sensing algorithms like vegetation indices and split window algorithms operating on the single pixel level. The brightness Index (Mariko et al. 2008) based on NOAA-AVHRR data sensitive to moisture of the ground will be tested complementary to proposed methods.

With the launch of the Spinning Enhanced Visible and Infrared Imager (SEVIRI) onboard the geostationary Meteosat Second Generation (MSG) satellite a new dimension has arisen within land surface remote sensing sciences; increased spectral resolution in the visible and thermal infrared domains combined with the detailed diurnal information obtainable from 15 minutes acquisition intervals. Especially the separate red (VIS 0.6) and NIR (VIS 0.8) channels and the two split window channels IR 10.8 and IR 12.0 are of interest for remote sensing of land surface processes like photosynthetic activity and surface temperature. The availability of the MSG data has new and promising perspectives for the use of the TVX method for estimation of air-temperature.

For a larger part of Africa specifically in Sahel area water stress is apparent because of the scarce water resources. Information on reflectance in the visible and near-infrared wavelengths can be used to derive vegetation indices such as the commonly

used Normalized Difference Vegetation Index (NDVI) (Tucker and Sellers, 1986) or the Enhanced Vegetation Index (EVI) (Huete et al, 2002). Several studies have focused on the derivation of EO-based information on plant water stress assessment using information from the near infrared and shortwave infrared wavelengths inspired by the laboratory findings (Gao, 1996; Huete, 2005). Fensholt and Sandholt (2003) developed a Shortwave Infrared Water Stress Index (SIWSI) based on MODIS data. SIWSI proved to be sensitive to variations in leaf water content and enabled an improved quality of primary production estimates in the African Sahel (Fensholt et al., 2006a).

SEVIRI MSG-data offers new opportunities for estimating vegetation water stress (Fensholt et al., 2006b). The new potential can be ascribed to the vast improvement in the temporal data availability (15 minute temporal resolution) overcoming problems related to persistent cloud cover. In addition, the diurnal variation of SIWSI can now be monitored and provides direct information on the level of water stress on vegetation. This approach will be pursued in the WANSEC for an improved EO-based plant water stress product for Africa feeding directly into Primary production modelling and Early Warning Systems (EWS).

## Participation

The partners involved will include:

- Technical University of Bamako, Mali
- University of Ouagadougou, Burkina Faso
- University of Dakar, Senegal
- Université A.M. Niamey, Niger
- University of Copenhagen

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**Annex C**

**Time Schedule**

## TIME SCHEDULE

Annex C/4

The project's main activities are divided into periods, together with the anticipated starting and completion dates (as a basis for calculating the size of the grant). Activities might include: field trips, data collection, participation in Ph.D. courses, teaching, dissemination and report writing. Planned vacation periods should be stated.

### The Principal Responsible Party:

Project Starting Date: 01/10/08  
Project Completion Date: 31/12/11

PERIOD:	HOST COUNTRY:	ACTIVITY:
October 08	Senegal	<b>Project initiation meeting.</b> The meeting will be hosted by the UCAD and each partner university will send at least one representative. Steering committee will be appointed and the project coordination assistant will be introduced to research members as well as steering committee.
Oct-Dec 08	All partners	Naming and introduction of Ph.D. students at each of the partner universities. Preferably this will take part <b>BEFORE</b> project initiation meeting, but all Ph.D. students should be identified before the end of the year. Clear descriptions of the Ph.D. projects must be submitted and approved by the steering committee no later than Dec 08.
Jan 09	Mali	Establishment of facilities for reception and analysis of satellite images and for GIS (ongoing activity throughout the spring of 2009). Initiation of sub-project on EO and water resources.
	Senegal	Initiation of sub-project on bush fires and on land use and land cover changes
	Ghana	Initiation of sub-project on peri-urban land use dynamics.

Jan-May 09	Mali	<p><b>PhD-course:</b> Research training and research project development and methodology. This course is mandatory for all Ph.D. students. Here the focus will be to integrate the Ph.D. students into the network and to help develop their project descriptions and to prepare field work campaigns.</p> <p><b>PhD-course:</b> Earth Observation: New sensors and new methodologies.</p>
May-Sep 09	All partners	First field work campaigns
Jun 10	All partners	A year after the Research training and research project development and methodology course all Ph.D. students will be required to submit a statement of progress. This will be used for the evaluation of the program and the progress of the individual students.
Jan-May 10	Burkina Faso	<p><b>PhD-course:</b> Earth Observation of vegetation and water resources</p> <p><b>PhD-course:</b> GIS and spatial modeling</p> <p><b>Second meeting</b> of the steering committee.</p>
May-Aug 10	Senegal	<p><b>PhD-course:</b> Joint field course. This course is envisaged to include common aspects of field work methods such as data collection and analysis, relevance to Earth observation of climate change etc. The joint field course will also be open for other Ph.D. students than WANSEC students.</p>
Jan 11-May 11	Ghana	<p><b>PhD-course:</b> Bush fires and the use of EO data in bush fire monitoring.</p> <p><b>PhD-course:</b> Urban and peri-urban land use dynamics</p> <p><b>Third meeting</b> of the steering committee</p>
Sep-Dec 11	Ghana	<p><b>WANSEC international workshop</b> on climate change in West Africa. Funds for this international workshop have not been included in the project. Rather, funding will be applied for together with other organizations working on similar topics. These include START and WARN.</p>