Type 1 Bimonthly Report #2

Title: Observations of the Plant Growth and Annual Flooding in the Inland Delta of the Niger River, West Africa (SR368)

Principal Investigator ID - UN431 (N.H. MacLeod)

Problems: No technical problems are presently impeding program progress. A management problem has arisen which was unanticipated. The program is associated with the Government of Mali's ERTS investigation, one which has considerable visibility. The results are of interest to a number of federal and international groups who wish current reports on the applicability of the remote sensing techniques employed by the AU project, that is, applicability to their own projects. This has resulted in a number of informal seminars, participation in field program analysis and - the problem- preparation for such consultations. This has resulted in the PI spending considerably more time in analysis and technique development than originally anticipated (one month). The problem is to adjust the program upward to the level of interest and response which it has generated. The current program includes one man month of time which cannot take full advantage of the present and potential results and benefits to be derived from the work. Perhaps the solution is the addition of more man-hours for support of the PI at AU.

Plans: Further analysis of the imagery using change detection and some digital procedures will be conducted. The PI plans to take vacation (two weeks) during an ERTS remote sensing seminar to be held in Bamako, Mali, April, 1973, during which he will be an instructor in the courses to be conducted. (The seminar is hosted by the Government of Mali and sponsored by US AID. Some twelve countries have been invited to participate. US AID will provide the PI's expenses, but there will be no salary-honorarium paid to him.) Cartographic products will be prepared, particularly of burned areas, vegetation in the Inland Delta, and the newly discovered drainage systems in western Mali.

Accomplishments: If getting to Mali and back to Washington during a dollar exchange crisis and an airline strike is an accomplishment, the PI did it. A two week trip to Mali was undertaken in February during which field trips, aerial reconnaisance and conferences with US officials and the Government of Mali PI - Mamadou Konate, were accomplished. An analysis of the possibility of ground water development in a potential 100,000 hectare ranch site was made in which ERTS imagery (including change detection photography done prior to the trip) aerial survey and geological inputs from the Malien PI were used. The use of ERTS data indicated that no surface ponding could be developed in the ranch site. The observation was confirmed by the air survey. Drill sites to test for the presence of a sufficiently shallow acquifer have been selected.

In 1964 a large basin on the Mali-Mauretanian border was known to have flooded, to have become a lake - but no one knew the source of the water.

We have since located the source on the ERTS imagery. It is one of the lineaments leading NW from the Office du Niger which was previously reported. The lineament is connected to the irrigation channels of the Office du Niger (a 250,000 ha irrigation scheme) and thus to the barrage on the Niger River at Markela which controls water flow into the Office du Niger. The basin, known as the Hodh, is located in the Sahara Desert and has potential as a large-scale irrigation project.

The previously reported sand-dunes in the lower Inland Delta were observed during the aerial reconnaisance and on the ground at Mopti. They are very flat sand fields with no dune development whatsoever. Instead they appear to be sheets of ground-water laterites some 60 ft thick at a minimum and overlain with a meter or so of sands and silts of alluvial and aerial origin. The flats produce some grass, are inundated during high floods, and are cultivated for grain production in some areas. The "soil" is poorly developed and droughty during non-flood periods. It supports very sparse vegetation only. The origin of these very extensive flats is not known. It is probable that the original forest vegetation asscciated with laterite development was removed at an early date for firewood and lumber. Some further search of the literature, including reports of explorers in the 19th Century, will be conducted to bring some sense of the original vegetation and use of this area into the picture.

Two national forest areas (fôret classé) were visited to acquire some field information on imagery content. The correspondence of drainage systems and field patterns is so good that little trouble was encountered in determining one's exact location on the image. Abandoned fields, tree plantations, conservation burning along roadways were identified in the imagery and then visited in the field. That is, we attempted to predict what we would see on site from the imagery and were very successful. We have fewer qualms about accepting our analysis of features in the imagery now. Some enclosed areas from which large animals and peasant cultivators are excluded were visited. These areas have heavy stands of grass, bush and trees, forming a tangled scrub plant community. Young tree seedlings with green leaves (February is in the middle of the dry season) were observed in all such stands. It may be that fully stocked forests will develop in enclosures in southern Mali in a relatively short period of time - 20 years.

Significant Results:

1. A large potential irrigation area with water delivery system in place was identified from ERTS imagery. The site is in the Sahara Desert.
2. Color additive change detection imagery was used to assess ground water potentials in the Savannah in conjunction with a major US AID-Mali livestock sector initiative.
3. The potential capacity to map laterite deposits in the Inland Delta from space was established with the help of aerial and ground surveyer.
4. (A color composite of the inland Delta could have saved French biogeographers 3 5/6 man-years of professional field work had it been available, according to the man who prepared a plant community map of part of the southern Inland Delta.)

Presentations: Several informal seminars were held with US GS and US AID, and IDA people here and in Mali. (The imagery used had been previously reported.) A paper was presented at the Symposium on Significant Results Obtained From ERTS-1. See attachment.

APPLICATIONS OF REMOTE SENSING (ERTS) TO RESOURCE MANAGEMENT AND DEVELOPMENT IN SAHELIEN AFRICA (REPUBLIC OF MALI)

N. H. MacLeod
Department of Biology
The American University
Washington, D. C.

ABSTRACT

The primary resource management problem in Sub-Saharan Africa (the Sahel) is increasing aridity or desertification. Space observations of sand streams, dune orientations, moisture and vegetation changes and other factors associated with desertification have been made. It is not yet known whether the process is caused by human activities or climatic changes or both.

A second major interest is grazing of cattle, sheep and goats which is associated with major movements of people and animals twice yearly to obtain forage -- from the savannah in fall and winter, and from huge areas of marsh (the Inland Delta) in spring and summer. These movements (transhumance) pass through more settled cultivators and into regions occupied by fishermen. The changes in available forage are being observed. The location of the cultivators is also being mapped from ERTS imagery -- for the first time. Field burning after rains is widely practiced and has been observed and the extent measured in ERTS imagery. In some areas of Mali, this measurement is an estimate of area to be planted to grain in the next season -- an unmeasured parameter heretofore.

Hydrological analysis is being carried on in the Niger and Bani River watersheds. The size, timing and areal extent of the annual flood is of particular interest. So far, good imagery of the maximum flood stage has been obtained and assessed.

Geologic information on fault zones, sand dune formations, scarps, tectonic basins and focal points of faulting (points from which fractures appear to radiate) are all visible and heretofore mapped inaccurately or not at all. The information on possible areas in which

mineralization has occurred are being mapped and noted for Malien officials carrying on their own ERTS investigations.

At the present time, the countries in the semi-arid zone of West Africa -- the Sahelien Zone -- are faced not only with the problems of economic development, but also with ecologic deterioration which they perceive to be a major and rapidly intensifying hazard.

The Republic of Mali in West Africa has recognized the problems of economic development and has also recognized that the data base of fund of knowledge concerning their natural resources is very meager. Maliens also recognize that the productive potential of the Sahelien Zone may bring their economy to a position of a major grain and livestock producer if they can control desertification and combine hydrologic and agronomic resources. They also recognize that their entry into world markets will be hastened by the discovery and development of mineral ores, energy sources (including geothermal), ground for crop and livestock production, water, and petroleum resources. Further, they realize their technical services, though staffed with able people, are inadequate for the performance of the necessary miracles.

Mr. Mamadou Konate, Director, Geological and Mining Services of Mali, in conjunction with U.S. AID, USGS and NASA technicians and members of the Malien technical services, is Principal Investigator of an ERTS-1 investigation through which the government of Mali (GOM) hopes to establish the necessary data base or resource inventory for long-range development planning in geology, hydrology, forestry, agriculture and grassland management. (I am speaking today both as a co-investigator in the GOM study and as a Principal Investigator for the U.S. "counterpart" ERTS investigation -- UN431). I have just returned from Mali, and I have the following report on our progress in analysis of the ERTS-1 imagery in relation to Malien development goals.

First, progress is being made in developing a detailed geologic map of the country (Figure 1). Overlays of geologic features drawn from the imagery of the Gao region are compared with recent maps drawn from French field studies. The major additions from the ERTS imagery are fault lines; more specific delineation of sand fields; and mapping of sedimentary pediments in the area. The Niger River, in this and other areas, follows lineaments apparently controlled by these. The Gao graben (a downfaulted block) is a feature of major interest because of its potential as a petroleum or water source. The western boundary of the graben has now been quite precisely mapped from the space imagery.

In the next sets of figures of the southern Inland Delta of the Niger River -- a tectonic basin (Figure 2), and the frame to the west, which contains a major irrigation scheme installed by the French (also

a tectonic basin), and the so-called Delta Mort or Dead Delta -- we can point out some major advances in understanding of the hydrologic and vegetation regimes. We find that the Niger and Bani Rivers follow courses which are similar in orientation to the major lineaments -- possibly fractures found throughout southern Mali. These lineaments have been described in the Bandiagara Highland to the east, but not in the lowlands. We had thought the arrow-shaped, light-colored structures were dunes. They have been mapped as such -- dunes which are thought to be several thousand years old. An aerial reconnaissance, coupled with a ground observation at Mopti (located at the arrow in Figure 2), showed these were barren flats -- actually laterite covered by less than a meter of sand. These flats are cultivated in some villages. They are flooded each year and are thus supplied with water. Millet, rice, and cotton are the major local crops. The presence of the lineaments has an interesting relationship to ground water supplies in the region -- a resource which the Maliens wish to develop for livestock production. In years of below-normal precipitation, the flow of water out of the Inland Delta is greater than can be accounted for by precipitation alone. The excess outflow must come from ground water. The question is where is that reservoir of ground water? We feel that the fractures may be either the reservoirs themselves, or that they act as channels for the aquafers supplying the extra outflow. These hypotheses can be rather inexpensively tested by drilling into the lineaments.

The Niger River floods each year as it carries off the precipitations associated with the north and south advance and retreat of the Intertropical Convergence (ITC) each summer. The flood crest takes about six months to flow downstream. On 22 September 1972, the date of this image, the flood crest was in the southern Inland Delta, shown here, and thus its aerial extent can be measured from this image. This is an important measurement for nomadic animal husbandrymen who bring their cattle into the Delta each year to forage, for the Bozo fishermen who harvest 50,000 tons of fish from the Niger each year, and, of course, for the cultivators in the Delta.

The question of desertification can also be examined in this image. The soil is sandy in most of the area, but one would like to examine what appear as deposits of dunes or regions of sand to determine the mode and time of their origin. One particularly intriguing area is that between the Niger and Bani Rivers where an unwatered river channel can be seen. There is no vegetation or water in the channel -- it is not a wadi or channel for an ephemeral river, for it would be watered at this time of peak runoff if it were. No one knows the answers, but the stream was not previously mapped. Is there no water because of increased aridity, or has the watershed been captured by the Bani or Niger Rivers? Why is there no vegetation? The discovery of the existence of this and other such unwatered drainage systems in southern Mali pose major hydrologic problems worthy of much further study.

In the northwest corner of the image, one can see a cuspid pattern of tones. This is an area of range for the Peul, a cattle-owning people. The different tones are caused by differences in the type of vegetative cover -- the darker tones correlating with scattered trees and shrubs, the lighter with open grassland. Color additive techniques can be used on successive images to determine the cahnges in available forage during the rain-free season and the zones of highest productivity.

In Figure 3 the irrigation scheme, Office du Niger, is a prominent feature. By digital analysis we have mapped the pattern of irrigation channels, irrigated fields, and the adjacent cultivator fields. We have also mapped temporal changes in vegetative cover and soil moisture in the region.

Surface runoff patterns are peculiar in the region west of the irrigation scheme. In the imagery we find some areas devoid of surface drainage-ways. Aerial reconnaissance showed us that this is indeed the case. We feel that soils are very porous in the area and that there is some hope of finding aquafers shallow enough to be developed for livestock water-points so that the range may be better utilized by nomadic cattlemen.

We were particularly pleased to find the lineaments trending northeast and northwest from the northern part of the Office du Niger. By bringing together our data resources, we found that the northwest lineament (which has a water-formed channel in it) leads to a large circular depression -- the Hodh -- on the Mali-Mauretanian border. In 1964 the depression was so filled with water that it became a lake -- even now there is surface water detectable in the imagery. However, no one knew the source of the lake water -- it was a "gift of God." So it was, but we have found the channel -- that to the northwest of the Office du Niger. It can be filled using existing structures by controlling water flow into the Office du Niger from the Niger River during the Niger flood.

A dry-bed stream channel is located in the west-central portion of the image. Obviously, a large flow of water was required to form the channel, which continues northward to the Hodh and beyond. In the Hodh region of the channel is more than two miles wide and is located in the Sahara Desert itself. Further studies must be carried on; but the stream beds, the lake bed, and the lineaments make an intriguing combination for one interested in mapping and developing surface and ground water resources in that region.

All of the Mali images are full of interest for many disciplines. We have not fully addressed the question of desertification, but the ability to map sand from the imagery has been demonstrated. We also are able to map much of the vegetation of Mali to set a baseline condition for further development of extensive, intensive, and irrigated

agriculture.

There are still fascinating questions remaining concerning the lineaments, some of which control the course of the Niger, the Bani, the shape of the Delta and the Office du Niger, and relationship of the lineament to the former drainage channels. The answers can be sought now that a data base is becoming available to reveal the nature of the land surface.

While these comments merely brush lightly over the concerns of development, merely stating some of the discoveries without fully considering their implications for improvement and without conveying all that has been done in analysis, one may surmise that at least the inventory of resources has begun. Just this beginning has already affected the planning processes of the Malien government and of aid-donor agencies. We are also acquiring an appreciation of the dynamics of the cultivator-nomad relationships, the climate and land-use, and a more quantitative approach to the desertification problem.

A further immediate outcome is the emerging understanding by all participatns in the project -- Malien and U.S. -- of the regional nature of problems confronting Maliens in evolving a new kind of economy and the interwoven fabric of her natural resources -- geologic, hydrologic, biotic, and human -- that can be mustered for the development.

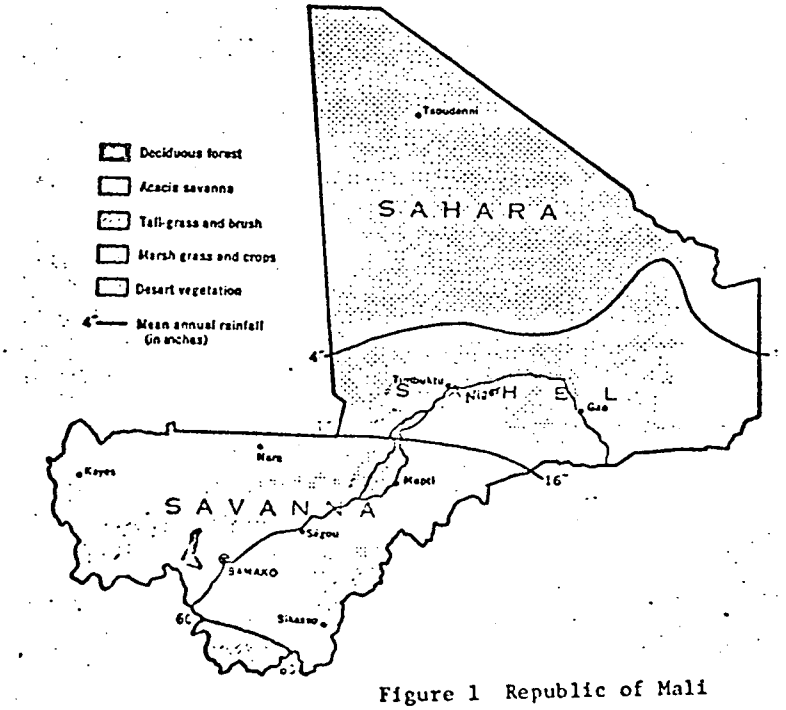

Figure 1 Republic of Mali