# INCLUDING GEOSPATIAL TOOLS FOR AGRICULTURE EDUCATION IN DEVELOPING COUNTRIES: A CASE FOR CAPE VERDE AND MOZAMBIQUE

**Marco Painho, Alexandre Baptista, Ali Atumane, Elsa Simões**

PhD, Marco Painho; NOVA Information Management School – New University of Lisbon; Campus de Campolide 1070-312 Lisboa; +351 213 828 610, painho@novaims.unl.pt

M.A, Alexandre Baptista; NOVA Information Management School – New University of Lisbon; Campus de Campolide 1070-312 Lisboa; +351 213 828 610, a.baptista@novaims.unl.pt

M.A, Ali Atumane; Faculdade de Agricultura – Universidade Católica de Moçambique; Rua do Aeroporto 22 Cuamba; +258 271 62 732, aatumane@ucm.ac.mz

M.A, Elsa Simões; Escola Superior de Ciências de Agrárias e Ambientais – Universidade de Cabo Verde; São Jorge dos Órgãos; +238 33 40 300, elsa.simoes@adm.unicv.edu.cv

***Abstract***
*Mozambique and Cape Verde suffer from a shortage of qualified specialists with geospatial skills for agriculture information management and precision farming.*
*To answer to a shortage of skilled work labor in a significant field in both countries, the NOVA Information Management School, in partnership with Universidade de Cabo Verde, Universidade Católica de Moçambique and the support of Esri Portugal and Trimble, conceived the AgIM Master Course.*
*Throughout the course, the students learn to use modern forms of positioning systems, computerized processing of maps and tools such as GPS, GIS, remote sensing and analysis of geo-referenced data.*
*To ensure the project's sustainability and to strengthen the human and institutional capacity of both partners, several training courses are currently put into practice.*
*The students have the opportunity to apply the acquired knowledge in two pilot demonstration projects. This methodology aims at multiplying the benefits of precision farming in local communities.*

***Keywords****: geographic information systems, education, precision farming, agriculture information management*

## INTRODUCTION

The concept of precision farming has emerged since the 1990s in various forms, depending on the knowledge and available technology. It is implemented in a combination between advanced information technology and full agricultural mechanization (Tran and Nguyen 2006). Within the precision farming related technologies, there are five key technologies: global positioning system (GPS), geographic information system (GIS), remote sensing, variable rate technologies and analysis of georeferenced data (i.e: geostatistics) (Chartuni et al. 2007).

The integration and advances of these technologies have led to several advantages to farmers, such as overall yield increase, efficiency improvement, reduced production costs, better decision making and reduced environmental impact (Tran and Nguyen 2006).

The application and implementation of precision farming in developing countries is limited due to high costs and knowledge demand. However precision farming should be regarded as essential in the development of agriculture in these countries, even if it is used in a different form to that offered in Europe an North America (Dobermann et al. 2004).

Several proposals were designed for application of precision farming in developing countries. Ram et al. 2014 presented the following methodology to be operationalized in India:

- Creation of multidisciplinary teams involving agricultural scientists in various fields, engineers, manufacturers and economists to study the overall scope of precision agriculture.

- Formation of farmer's co-operatives since many of the precision agriculture tools are costly (GIS, GPS, remote sensing, etc)
- Government legislation restraining farmers using indiscriminate farm inputs and thereby causing ecological/environmental imbalance would induce the farmer to go for alternative approach.
- Pilot study should be conducted on farmer's field to show the results of precision agriculture implementation.
- Creating awareness amongst farmers about consequences of applying imbalanced doses of farm inputs like irrigation, fertilizers, insecticides and pesticides.

In Mozambique and Cape Verde, two nations considered by the USAID as developing countries (US Aid 2012), there was no higher education institution offering a degree in precision farming. Given the shortage of qualified professionals with geospatial skills and the importance of agriculture to the economy of both countries, the NOVA Information Management School (NOVA IMS) developed a consortium with Universidade Católica de Moçambique (UCM) and Universidade de Cabo Verde (UniCV), in order to create a postgraduation and master course in agriculture information management and precision farming in both higher education institutions, the AgIM Project.

This paper is organized in 6 sections (excluding this introduction): section 1 is focused in agriculture education in developing countries. Section 2 is dedicated to the AgiM course and the pedagogical model. Section 3 is focused in the geospatial tools that the students learn at the course. Section 4 adresses the academic success on the course. Section 5 presents the methodology and some results of quality assurance processes at the course. Section 6 is dedicated to the sustainability of the project

## AGRICULTURE EDUCATION IN DEVELOPING COUNTRIES

In developing countries the major source of funding and financial support for agricultural education are usually the national or regional governments. In general higher education institutions in these countries operate by an annual budget dependent on government funding, tuition fees and other sources of income (donations, revenue from farms in agriculture departments, etc) (Chittoor and Mishra 2012).

The case of agriculture education is very specific due to excessive costs. Indeed it requires materials, scientific and technical equipment, adequately equipped training and experimental farms (Chittoor and Mishra 2012). Usually the maintenance of thse facilities is beyond the financial resources of these institutions.

According with (Chittoor and Mishra 2012), with few exceptions the institutional relationships between agriculture teaching and research and extension are inadequate. This situation is result of separation between education, research and extension into different ministries and agencies and weak mechanisms to link them together. This issue is linked with one the biggest challenges that agriculture education, specially in Africa, has to surpass: providing education and training for rural development than agriculture alone (Vandenbosch 2006). To address this issue, education and training needs to be applied rather than only theoretical and the institutions need to incorporate the dynamics between:

- Food security.
- Environment: soil erosion, desertification, deforestation, environmentaly damaging agricultural practices, water shortage, drought and climate change.
- Economics: effects of globalization, trade liberalization, market deregulation and agri-business management.
- Population: Impact of population growth on agriculture and natural resources, basic demography, gender issues and HIV/AIDS impacts.
- Technological and scientific progress: food processing and post-harvest technologies and biotechnology.

Another concern is the availability of teaching and learning support materials (Vandenbosch 2006). When teachers are competent and well trained, it is often difficult to teach effectively due to the lack of learning support materials (resource books, equipment, tools and materials) or inadequate curricula (not relevant for the needs of farmers and labour market in general).

To address these challenges, it will be necessary to transform the agriculture education institutions from academic isolation and become active contributors to sustainable agricultural and rural development through innovative teaching, research and extension (Chittoor and Mishra 2012). This can be achieved through new educational strategies, innovative

and creative leadership and institutional reforms that take into account the current trends that influence agriculture and rural development.

## THE AGIM MASTER COURSE

The AgIM (Agriculture Information Management and Precision Farming) Project, was developed in cooperation between the NOVA IMS, as applicant institution, the Faculdade de Agricultura (UCM), the Escola Superior de Ciências Agrárias e Ambientais (UniCV) and with the support of Esri Portugal and Trimble. The Project is financed by the EDULINK II Program (funded from the European Comission) and the main objective was to implement a master course programme with a curriculum based on best practices in agriculture information management and precision farming in both partner institutions, taking into account recent advances and specific conditions for its introduction in developing countries.

In parallel with the course, another feature of the project is the establishment of two pilot demonstration projects (one in each country), which play a decisive role in applying the knowledge acquired throughout the curricular units. The pilot demonstration projects are the base of a repository of practices and fieldwork in adapting and updating the methods and techniques to the reality of both local farmers and communities. It implements a set of activities, giving students the opportunity to learn methods of integrating precision farming and decision-making processes. As a result, it is expected that students successfully meet the six steps defined by Kitchen et al. (2002) in the adoption and application of precision farming:

1. Understanding the concept of spatial data, its management and importance.
2. Learning the use of technologies (GPS, remote sensing, etc) that contribute to the collection of data information at low-cost.
3. Learning GIS (geographic information systems) software.
4. Understanding the factors that influence the extent, stability and income from agricultural activity.
5. Conducting fieldwork to understand the causes of variability (integrating local knowledge with technical expertise).
6. Optimization by sampling and testing on site.

It is expected that the students will be able to do acquisition of land related information and production data and its integration in GIS applications, classification of agricultural camps in georeferenced zones based on soil characteristics and production potential, assessment of the specific type of suitable cultivation areas, based on the analysis of geospatial data.

The course started in March 2014 in Mozambique and due to the differences between the academic year in Mozambique (from January to December) and Cape Verde (from September to July), the AgIM course only started at UniCV in September 2014. Currently the course has 28 students (from both countries) and although most of the students have an academic background in agriculture, some have training in computer engineering, public administration and biology.

During the first semester the students had field work classes in local communities where they acquired geographic data (with GPS devices provided by the project), soil samplings and interviewed small producers (figure 1).

*Figure 4. AgIM students and a local farmer using a GPS device*

The geographic data collected by the students will be displayed in a WebGIS at the AgIM website. A WebGIS give the ability to think spatially and to solve real-world problems. It also can teach students to llok at issues from a local to a global scale (Fu and Sun 2010).

The first academic year in Mozambique ended in December 2014 (and in Cape Verde in June 2014) with the presentation of the projects developed by the students in the 2nd semester. The students that completed all the eight curricular units are currently preparing their dissertations for obtaining the master degree in agriculture information management and precision farming. Currently 29 students from both institutions finished the first (curricular) year (as of March 2016). Of these, 5 students already finished and presented the dissertations.

Between the inception of the course and January 2016, 9 teachers from NOVA IMS (and 2 local teachers) delivered 26 curricular units, 13 training courses and 6 final project presentations (figure 2) in Mozambique and Cape Verde.

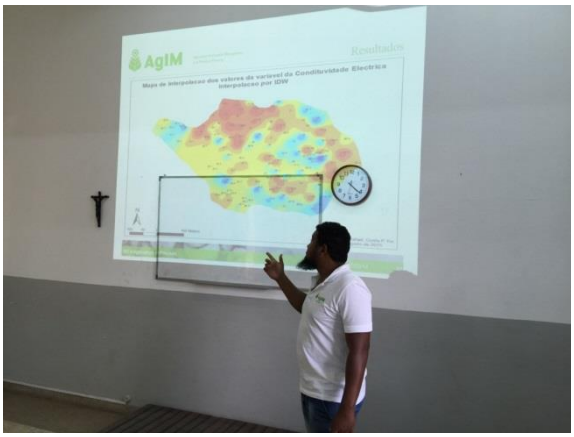


*Figure 5. AgIM student at a project presentation*

Besides the development of a top-level master course in precision farming, the partner institutions and the students benefit from the contribution of software and education resources related with the AgIM master programme. The administrative and IT staff also benefit from a set of training courses, targeted to improve management and technologic capacity.

The training courses were held in both partner institutions, with nearly 150 attendees in both partner institutions. For the teaching staff, the following courses were organized: problem-based learning (PBL), curriculum development theories and educational technologies. The first two courses focused on PBL methodology and curriculum development. The educational technologies course was targeted on the organization and management of e-learning platforms with special focus on Moodle. For the academic and management staff it was developed a course on international project management.

The students and local agriculture technicians attended two technical training courses: the current state of the art of precision farming and UAV AgIM. In the first course, the students received training in state of the art approaches and methodologies and techniques used in precision farming. The second one was dedicated to UAV's (unmanned aerial vehicles) and its use in precision farming.

In the UAV training course, it was used a relatively affordable drone, meeting the goal of adapting precision farming in developing countries. The students were able to use to drone to acquire aerial and multispectral imagery and area measurement.

The main beneficiaries of the action are the local communities, consumers, commercial/agribusiness organizations, other educational organizations, researchers/research institutions, other students, local authorities, public administration and non-governmental organizations.

The local communities will obviously be the main beneficiaries, benefiting with the help of these technicians, they will have a better understanding of more sustainable and profitable agricultural techniques. Thus, it is expected to create a strategy to reduce rural poverty, improved food security and natural resource management. These improvements are expected since the project AgIM is a pioneer in postgraduate education in precision farming and agriculture information management in the two countries involved. In addition to the training of specialized technicians, it also will test the adaption of precision farming technologies in small rural communities that essentially practice the activity as a means of subsistence.

## Pedagogic Model

The AgIM Master course lasts for three semesters and comprises a number of curricular units of mandatory nature. The course's first semester consists on four curricular units that provide skills and knowledge considered essential to meet the defined objectives for the program: GIS and Precision Farming, Remote Sensing and Spatial Analysis, Research Methods and Data Acquisition. The second semester features a set of four courses with a higher level of specialization and depth: Quantitative Methods, Precision Farming, Agriculture Information Management and, Implementation of Precision Farming in the Community.

The objectives and curricular units' contents aim at the acquisition of skills required for the continuation of the process of learning and knowledge, promoting scientific research, use of techniques and adequate approaches to solve complex problems in the field of agriculture information management and precision farming.

The third semester is dedicated to the preparation of the dissertation. Obtaining a post-graduate degree is dependent on the achievement of credits associated with the eight curricular units in both the 1st and 2nd semesters (1st year). The attribution of the master's degree requires, apart from approval in the curricular component of the 1st year, the preparation of a dissertation, discussion and its approval.

The courses are taught sequentially. The beginning of a course necessarily coincides with the end of the course that precedes it. Each course has a duration of 5 weeks (figure 3).

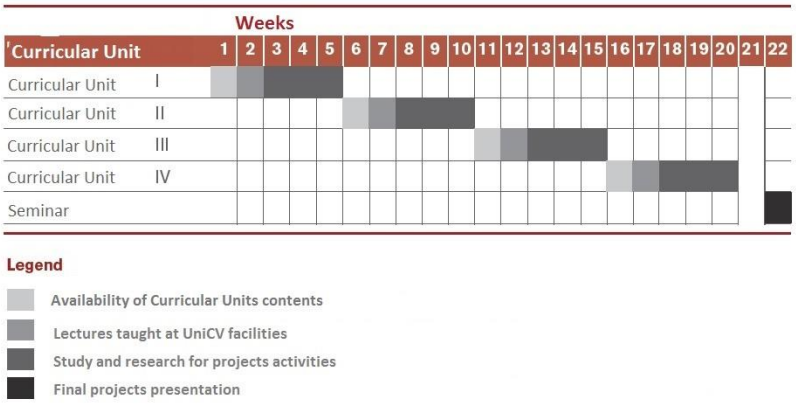


*Figure 6. Curricular units weekly sequence*

At the end of each semester, the students have to present and discuss the projects (one per curricular unit) developed during the corresponding period. The discussion sessions are open and in addition to teachers, students and staff of the partner institutions, NGO's elements, citizens, local producers, among others can attend it.

The AgIM course is developed in a blended learning format, with face-to-face classes and eLearning interaction (in a Moodle platform). According to (López-Pérez, Pérez-López, and Rodríguez-Ariza 2011), blended learning improves students' learning experiences by developing their capacity for reflection.

In the first week of each class the teachers have to upload the curricular units' contents in the Moodle platform. The second week is dedicated to the presential classes and in the last three weeks the students have to develop the final project. One of the advantages of using a elearning method which can be more adaptive than conventional learning (Bachari, Abelwahed, and El Adnani 2011). The platform is always available anytime and anywhere. The only schedule that the students need to follow are the presential classes and the session of discussion of the projects developed during the curricular units.

## GEOSPATIAL TOOLS IN AgIM

The AgIM master course is deeply focused on the use of geospatial tools and its use on precision farming. From the eight curricular units of the course, only one, Research Methods, does not have in its curriculum the use of geospatial tools.

In the GIS and Precision Farming curricular unit, the students learn the bases of GIS and its role in the development of precision farming. In Data Acquisition, the students gather data (with the use of GPS devices) in local agriculture fields, that are used for the pilot demonstration projects (PDP). This curricular unit is vital for the course, due to field work

experience, the importance of the gathered data, that is used by the students as study case in the PDP's and in some of the student's dissertations.

In Remote Sensing and Spatial Analysis, the students learn the basic principles of remote sensing, identify the main sources of geographic data for creation, edition and modelling. In Quantitiative Methods the students learn to explore and interpolate the geographic data from Data Acquisition.

Another main curricular unit is Precision Farming, there, the students use spatial information in the design of intelligent soil sampling and learn the importance of geoelectric sensors in the analysis of spatial variability of soil quality. In Agriculture Information Management although the students don't directly use geospatial tools, they learn how to create and manage databases. In the last curricular unit, Implementation of Precision Farming in the Community, the students learn the concept of Public Participation GIS and how to create it.

The use of geospatial tools in AgIM is implemented gradually, starting from the the concept of GIS to spatial variability and creation of online maps. Not only the students graduate in Agriculture Information Management and Precision Farming but also are able to become skilled GIS technicians.

## ACADEMIC SUCCESS

In the AgIM Master course, although each curricular unit has its own means for evaluation during the presential classes, it varies from work groups and presentation in class or evaluation of participation from the students, there are evaluation elements that all curricular units follow.

The evaluation elements that all curricular unit follows are a exam at the end of the presential classes and a project to be presented by a student or a group of students at the end of the semester. As mentioned in the previous chapter, each course has a duration of 5 weeks, the second week corresponding to the presential classes, at the end of that week (Monday to Friday in Mozambique and Thursday to Monday in Cape Verde) the students do an exam. During the following weeks until the next curricular unit, the students (individually or in group) develop a project to be presented at the end of the corresponding semester. The presentation sessions are open to public, so any local producers, local coummunities and other teaching staff can assist it. The project is the most important evaluation element for the students. Usually worths more than 50% of the final grade by curricular unit.

At UCM, in both editions, from a total of 23 students, only two didn't successfully finished all the curricular units. From these 23 students, 3 had 15 or more in the final average grade (the AgIM course follows the Portuguese grading system, where the maximum grade is 20 and the passing grade is 10). At UniCV the second edition is currently ongoing, but in the first edition, all the students completed with success the curricular component of the course. Two students had 15 or more in the final average grade.

After the conclusion of the curricular component of the course (approval in all curricular units), the students with the support of the supervisors start to develop the dissertations. As of April 2016, five students already presented their thesis, from those 3 had a grade of 15 or more.

## QUALITY ASSURANCE

There is a focus on quality assurance that is related not only with the post-graduation and master course with but also with its sustainability. An anonymous and confidential evaluation system is implemented. This evaluation procedure is performed every semester, for every curricular unit and is based on international quality assurance standards. In addition to the students' evaluations of each curricular unit, students also assess the study program at the end of each semester. Currently all the teachers and curricular units evaluated by the students in both institutions, received good classifications, which reflects the level of satisfaction of the students regarding the course.

The quality in the course is also evaluated through the students ratings and performances, by considering the following methods of assessment: tests, exercises, assignments, term papers, lab reports, classroom participation, final project and final seminar.

To create a reference master course in agriculture information management and precision farming, a special focus was given to the accreditation and recognition by the competent authorities. Each partner institution developed a dossier that was delivered to each country Education Ministry that subsequently recognized and gave accreditation to the course.

Twice a year, the project organizes quality assurance meetings (one in each partner institution), where the project coordinator meets the local coordinators and quality assurance managers. There the questionnaires answered by the sutdents in each curricular unit are analyzed. The meetings also ensures that the project activities meet or exceed the

international standards and that the curriculum structure and content, as well as the learning/ training events are consistent with the current state of science and technology in AgIM.

## SUSTAINABILITY

The sustainability of the course is one of the main objectives of the project, in this case it is expected that the course can continue beyond its implementation period (March 2017). To ensure the sustainability it is important to have a local teaching staff skilled in precision farming. To achieve this, the best students of the first edition in each partner institution were selected to support the NOVA IMS teachers in the presential classes of the second edition (16 students were selected in these conditions). At UCM it is currently undergoing the third edition of the course, completely organized locally, it is being managed by the local coordinator and the teaching staff is composed by students from the first and second editions.

At institutional level, the sustainability is ensured through the organization of the training courses for academic, IT and administrative staff, that with the skills provided by the project can try to secure adequate resources for the continuity of the action and to increase it in winning international funding projects from major donors.

Besides the institutional level, the sustainability at environmental level is also taken in account. With implementation of the pilot demonstration projects and the increased number of skilled professionals in the area of precision farming will contribute tot the promotion of more targeted use of inputs and reduction of losses due to nutrient imbalances, weed escapes, insect damage, etc. at least in a local level. The implementation of precision farming by the students and the new professionals in local agriculture fields can also contribute to the reduction of poverty due to a improvement of the and better management of the fields and production.

## CONCLUSION

The AgIM project has a set of main objectives in order to deliver a successful and sustainable master course in Agriculture Information Management and Precision Farming. Currently, the majority of the objectives is accomplished, and remaining will be fulfilled at the end of the implementation period (March 2017).

As of April 2016, 19 teachers from Mozambique and Cape Verde teached in the course, three of them were already in the starting teaching staff, the remaining 16 are students (eight from each country). Besides the qualification of the students, the organization of training courses for academic, teaching and IT staff contributed for the improvement of the partner institutions. 12 training courses were already delivered (there are only two courses remaining until the end of the project). Nearly 100 students, teachers, academic staff and local producers participated in the training courses.

Both the classes and the training courses are the main contributors for the Pilot Demonstation Projects (PDP). The PDP's work as a training field for implementation of precision farming and its adaptation for the reality of Mozambique and Cape Verde. There the students execute soil samplings, data collection through GPS devices (acquired by the project and donated to the partner institutions) and use ArcGIS for compilation of geographic data. For the improvement of data acquisition, until the end of 2016 a UAV will be donated to UniCV and UCM.

The master course is already recognized by the competent authorities in Mozambique and Cape Verde and due to its pioneer status and the objective of adapting precision farming to the reality of the local producers in both countries, it is expected to create a guideline to disseminate and stimulate good practices in precision farming. To support this guideline, at least one of the partner institutions will create a conference in precision farming in developing countries. There the students can present papers based on their dissertations and publicize their results and main conclusions. These results will be organized and published in proceedings.

## REFERENCES

Bachari, Essaid El, El Hassan Abelwahed, and Mohammed El Adnani. 2011. "E-Learning Personalization Based on Dynamic Learners' Preference." *International Journal of Computer Science and Information Technology* 3 (3): 200–216. doi:10.5121/ijcsit.2011.3314.

Chartuni, Evandro, Francisco De Assis De Carvalho, Daniel Marçal, and Emilio Ruz. 2007. "New Tools to Improve Technology Management in Agricultural Enterprises." *Technology and Innovation*: 24–31.

Chittoor, Jhansi Seetharam, and Santosh Kumar Mishra. 2012. "Agricultural Education for Sustainable Rural Development in Developing Countries: Challenges and Policy Options." *Journal of Education and Learning* 6 (2): 119–132.

Dobermann, Achim, Simon Blackmore, Simon E Cook, and Viacheslav I. Adamchuk. 2004. "Precision Farming : Challenges and Future Directions." In *4th International Crop Science Congress*, 1–19.

Fu, Pinde, and Jiulin Sun. 2010. *Web GIS: Principles and Applications*. 1st ed. Redlands: Esri Press.

Kitchen, N.R., C.J. Snyder, D.W. Franzen, and W.J. Wiebold. 2002. "Educational Needs of Precision Agriculture." *Precision Agriculture* 3 (3): 341–351. http://link.springer.com/article/10.1023/A:1021588721188.

López-Pérez, M., M. Carmen Pérez-López, and Lázaro Rodríguez-Ariza. 2011. "Blended Learning in Higher Education: Students' Perceptions and Their Relation to Outcomes." *Computers & Education* 56 (3): 818–826. doi:10.1016/j.compedu.2010.10.023. http://www.sciencedirect.com/science/article/pii/S0360131510003088.

Ram, Tulasa, Shiv L. Lohan, Ranveer Singh, and Purshotam Singh. 2014. *Precision Farming: A New Approach*. *Daya Publishing House*. New Delhi.

Tran, D.V, and N.V. Nguyen. 2006. "The Concept and Implementation of Precision Farming and Reice Integrated Crop Management Systems for Sustainable Production in the Twenty-First Century." *International Rice Commission Newsletter*. Vol. 55.

US Aid. 2012. "List of Advanced Developing Countries A Mandatory Reference for ADS Chapter 310."

Vandenbosch, T. 2006. "Post Primary Agricultural Education and Training in Sub-Saharan Africa: Adapting Supply to Changing Demand."

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## BIOGRAPHY

Professor Marco Painho is currently a Full Professor at NOVA Information Management School of the New University of Lisbon. He has a degree in Environmental Engineering from the Faculty of Science and Technology of the New University of Lisbon, a Master of Regional Planning from the University of Massachussets at Amherst and a PhD in Geography from the University of California. His main research interests are Geographical Information Systems and Science, Decision Support Systems, Spatial Analysis, GIS education and distance learning (e-learning).

Alexandre Baptista is currently a Project Manager and Researcher at New Technologies Laboratory of the NOVA Information Management School of the New University of Lisbon. He has a degree in Geography from the University of Lisbon, a Master on Land Management and Urban Planning from the University of Lisbon. His main research interests are Geographical Information Systems, Spatial Analysis, GIS education and distance learning (e-learning).

Ali Atumane is currently the administrator of the Faculty of Agriculture of the Catholic University of Mozambique. He has a degree in Economics and a Master on Geographic Information Systems from the Catholic University of Mozambique.

Elsa Simões is currently the dean of the School of Agrarian and Environmental Sciences of the University of Cape Verde. She has a degree in Agriculture by the Louisiana State University and a Master in Quality Management and Agricultural Food Marketing. Her main research interests are agriculture development, river basin management and agroindustry