2. REMOTE SENSING TECHNOLOGY AND GEOGRAPHIC INFORMATION SYSTEMS APPLIED TO AGRICULTURE

Remote sensing broadly refers to measuring reflected electromagnetic energy using specific analog or digital sensors. The application of this technology in agriculture makes use of a wide range of instruments mounted on various platforms. These range from hand-held radiometers on the ground, aerial cameras, to optical and radar sensors mounted on satellites orbiting the earth.

The first experiments using hand-held radiometers for the measure of crop canopy electromagnetic reflectance and temperature, were conducted in the early sixties. The variables measured by these instruments were considered possible indicators of stress to be used for irrigation scheduling and this can be considered the beginning of remote sensing being applied to agricultural management. *(Nieuwenhuis et al., 1990)*

A decade later, the first satellite for the study of natural resources was launched with the goal, amongst others, of providing operational remote sensing information on crops to the farming community. Satellite remote sensing technology, just as traditional aerial photography, held great promise for the development of new approaches to farming. Decision-making would no longer be based exclusively on the farmer's experience of the complex interaction of crop, soil and climate or on complicated modelling procedures, but more simply on the encompassing and objective observation of crop performance in the field and on early warning tools *(Morgan, M. et Ess, D.)*.

Soon enough, however, some basic shortcomings became evident. Resolutions in the order of 80, 30 or even 20 m for the first generation satellites proved inadequate for some crops *(Moody A., http://www.unc.edu/~aaronm/RSCC/.)*. Besides this, the uncertain availability of images due to cloud cover, the sometimes excessive time lag between acquisition and delivery of the imagery and, finally, cost, made satellite remote sensing virtually unavailable for farm management. All the same, agriculture benefited from this new technology for climate monitoring, food security, regional crop statistics, modelling, resource inventories, land cover mapping, etc.

In the nineties further development of instrument technology and the availability of digital airborne video and cameras provided new impetus to the application of remote sensing technology in everyday farming. *(Goddard et al., 1996)*

It is possible today to fly a digital camera or video, record very detailed images of fields, process and make them available to the farm manager within hours of acquisition, and, all this, at an affordable cost. This technology stemming from traditional aerial photography, plugs into all the expertise and applications built on and around satellite remote sensing, bringing with it the advantages of digital technology as far as ease of data handling is concerned.

Additional benefits of airborne digital remote sensing are a much wider flexibility in operations with respect to orbiting sensors. Survey instruments can be operated from airborne platforms with the ability to customise the acquisition process to the specific requirements of the end-user in terms of target selection, timing and resolution. It is, by all means, a transition technology, because the future will see satellite sensors overcome the present limitations in terms of resolution and data availability. There will, most probably be constellations of satellites that will guarantee the constant imaging of any point on the earth at any given time and at a high resolution. This technology however is not yet available, and will not be for some time to come. *(http://www.space.edu/projects/book/chapter27.html).*

Returning to the present, however, the images and data provided by airborne digital sensors can be used for resource evaluation and in the development and operation of a wide range of other applications that will maintain a technical livelihood in future satellite technology.

These applications, as far as the agricultural sector is concerned, are commonly based on the 'imaging' of the crop or of the soil. The images that are collected can be either black and white, colour or multi-spectral, according to the type of instrument that is used. For black and white or colour images, the retrieval of the information relies on the ability of the expert to interpret shapes and colours.

In the case of multi-spectral and hyper–spectral imaging, information can also be obtained by measuring the intensity and variations that the reflected electromagnetic energy can assume within specific ranges (bands), some of which are outside the normal spectral range to which the human eye is sensitive.

Each band of information contains important and unique data, and the different wavelengths of incident electromagnetic energy are affected differently by the characteristics of the surface. These can be absorbed, reflected or transmitted in different proportions. Knowing the central wavelength positions for each band, these proportions of reflected energy can be measured to identify vegetation types, growth stage and health. Over time, these bands can monitor changes in these conditions. The combination of various reflected wavelengths provides a 'spectral signature' for the specific crop canopy and/or soil surface *(Price J. C., 1994)*.

The agricultural sector will derive great benefits from these new capabilities in operations such as irrigation scheduling, integrated pest control or precision farming techniques. These last applications in particular, imply the identification of within-field soil and vegetation anomalies, and variability in the quest to calibrate and optimise inputs to requirements and maximise cultivation efficiency[2].

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[2] (***http://www.cnn.com/NATURE/9911/15/remote.sensing.enn***)

However, while instrument technology, driven by the commercial interests of manufacturers, is rapidly progressing, the development of suitably advanced applications is lagging behind. This is largely due to costs, a certain technological delay in the agricultural research sector, and the fact that every-day crop management is still actively carried out according to 'traditional' lines. New technologies have to face some inertia, if not opposition, in proving their effectiveness. There is consequently a wide range of opportunities to analyse the information that images can provide. The detailed resolution and the capacity to discriminate and gauge physiological conditions of crops is extremely important in supporting farm management decisions, thus allowing a significant optimisation of cultivation practices and technical inputs.

Similarly to the empowerment brought about by remote sensing in the capacity of 'looking' at fields and crops, GIS technology has completely changed and enormously increased the capacity to analyse spatial data. GIS is a fast moving, continuously developing field, and the definitions of a few years ago may no longer be appropriate to current technology:

'A Geographic Information System is a group of procedures that provide data input, storage and retrieval, mapping and spatial analysis for both spatial and attributes data, to support the decision making activities of....' (Grimashaw, 1994)

Digital data in a GIS represents the world on a computer in a similar way that conventional maps represent the world on paper. GIS technology offers quick access to data and a lot more spatial information referred to the same location can be stored at the same time.

In the GIS environment, data can be attained in two different formats, namely, raster and vector data. Vector data represent geographic features as point, line or polygon objects that specify locations or boundaries. Raster data represent geographical features by dividing the represented surfaces into discrete cells called pixels[3], for each of which a 'describing value' is stored. An image is the simplest form of raster data.

In South Africa, airborne digital imaging as well as GIS technology for agriculture has over time, been tested by the Agricultural Research Council (ARC), the Council for Science and Industrial Research (CSIR) and a number of Universities.

At the end of 1996, the ISCW conducted a number of test flights using an Australian instrument, the STS-DMSV (SpecTerra Systems - Digital Multi Spectral Video). The tests were conducted over agricultural, forest and natural vegetation targets, and provided very encouraging results. The instrument was purchased in 1997 and a semi-operational development program was initiated.

The long-term goal of this program is the achievement of a cost effective and efficient service, providing near-to-real time management support information to farmers based on value adding to remotely sensed digital imagery.

[3] **Pixel**, short for picture element; One spot in a rectilinear grid of thousands of such spots that are individually "painted" to form an image produced on the screen by a computer or on paper by a printer. A pixel is the smallest element that display or print hardware and software can manipulate in creating letters, numbers, or graphics.