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GeoInformation studies of soil and vegetation patterns along Climatic Gradients: A Review

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Global evidence regarding magnitudes of desertification processes and recognition in their societal, ecological and climatological consequences had lead the international community to establish the United Nations Convention to Combat Desertification (UNCCD). Within the framework of this convention it is perceived that Desertification is a complex poorly understood phenomena which is " first and foremost, the result of resource management failures". Scientific research within this context have three primary roles: monitoring the situation, developing the understanding of relationships between factors promoting desertification and finally providing the international community with efficient recommendations regarding actions which may slow down these processes.

Study of desertification processes in regions of sharp climatic gradients is of special importance within this framework since they represent areas where the processes are most intensive and where most deserts actually expand. The detection of threshold zones coupling sever land degradation with loss of resilience in their eco-geomophic systems is fundamental for the efficient combating of global desertification. Application of geoinformation tools and techniques is instrumental for this purpose: mapping biological, chemical and physical surface properties using remote sensing techniques, mapping historical patch-pattern changes using air-photographs, analysis of spatio-temporal variations in pattern properties and analysis of informational relationships between these surface properties and patterns with climatoloical, topographic, lithological and human factors.

Numerous Remote Sensing studies had been undertaken during the last four decades in monitoring desertification through the provision of maps describing spatial distributions of biophysical surface parameters at resolutions between few meters to few kilometers and temporal resolutions between hours and weeks. These studies utilized radar backscattering , spectral reflectance at the visible, NIR and SWIR ranges and emissions in the thermal spectrum. However, despite the magnitude of these projects very few of the methods were proved to be operational yet. The main shortcomings of exiting methods are:

- They are highly dependent on accurate calibration which for large region is impractical.
- Most of the methods are semi-empirical: case dependent rather than representing robust physical indicators.
- There is no one imagery source which is good for all mapping purposes, most of the methods use single imagery source and there is relatively little synergy (fusion) between imagery sources.
- Data continuity for long time periods exits mainly for low resolution sources which are limited in supporting modeling of processes.
- Difficulties in scaling-up results and methods from the local to the broad-regional scales

Within the scope of interest here the most important shortcoming concern the fact that relatively little work treated explicitly regions of high climatic gradient partly due to their high spatio-temporal heterogeneity.

Three areas of recent advancements in studying explicitly transition zones between humid and arid regions :

- Mapping bio-physical properties of vegetation forms (herbaceous, dwarf-shrubs and shrubs): cover proportions, biomass, primary productivity using synergy between optical (phonologies) and SAR imagery.
- Mapping chemical and physical soil properties and estimating their erodibility using hyper and multi spectral methods, and SAR backscattering.
- Mapping soil and vegetation patch patterns and their changes within the last decades using historical air-photographs.

These advancement s lead to the detection of threshold zones between regions along these gradients according to following indicators:

- Life-forms compositions, biomass and primary productivity. Analysis of relationships between biomass and rainfall allow differentiation between cases were vegetation compositions and properties which follow ’expected’ successional sequences and those which represent harsh land degradation with productivity significantly less than would be expected according to their average annual precipitation.

- Soil chemical compositions referring mainly to organic carbon, inorganic carbon and ferrum. These mapping allowed the detection of ’tipping points’ in the high transition zones.

Analysis of historical patch-patterns ’ evolution modes using air-photographs and GIS techniques allowed insight into soil and vegetation pattern dynamics. Recent results had revealed that in some areas of low biomass there is maintained similar pattern fragmentation as in areas of higher rainfall. This signifies the functioning of self-organization and consequently the potential resilience of some areas of relatively low primary productivity located at desert margins.

In conclusion, current geoinformation tools and techniques on one hand had shown their potential contribution to the modeling and understanding of desertification processes in general and the formation of thresholds through the functioning of ’tipping’ mechanisms and ’catastrophic shifts’. However, these tools and techniques are not yet operational at the wide regional scale. Better synergy of remote sensing sources and availability of longer time series of surface properties will facilitate the combat of desertification with both better understanding of the processes and predictions of expected spatial change in different warming and human disturbance scenarios.