GeoS4S Module Geospatial Support for Arid Ecosystem Management

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Abstract
Various arid ecosystems formed in arid and semi-arid environment which almost cover 40% of continental land in the earth. It is fragile to any disturbance by both natural and anthropological factors. Management of arid ecosystem sustainability requires various geospatial data and methods for systematic monitoring, modelling, simulating and predicting of its processes and trends of changes in space and time. This teaching module employs case studies and interactive exercises to introduce the basic concepts of arid ecosystem and geospatial support for arid ecosystem management. Its high-level goal is to prepare the students for designing arid ecosystem monitoring, modelling and predicting system using existed geospatial data and methods online. The current paper summarizes the learning objectives, lesson content, learning activities and evaluation scheme for this module.

Key Words: Arid Ecosystem, Ecosystem Structure, Ecosystem Monitoring, Ecosystem Modelling Remote Sensing, Geospatial Data, SWAT, Arid Ecosystem Management

1. Introduction

Arid land is home to about 30 % of world population where lack of water resources but most productive zone due to the rich of radiation energy to drive ecosystem functions such as photosynthesis, water cycling etc. To understand and management of structure, functions and processes of arid ecosystem is still challenging due to great variety of available water resources not only in a local certain river catchment but also wide area even cross country river basin over time. The geospatial technology made it possible to monitor, model and predict all factors in ecosystem by remotely sensed data, field measured data together with modelled data is space and time to support sustainable management of arid ecosystem. This module will help ecosystem researcher, manager and decision makers to recognize usefulness of the geospatial support for arid ecosystem management.

1.1 Module Description

Tremendous geospatial data produced and stored even shared freely online thanks to development of geospatial technology in the past two decades. Various remote sensing satellites acquiring land surface, atmospheric, even sub-surface parameters directly or indirectly. Super computing and cloud computing capacity made it possible to extract many ecosystem and environmental parameters from remotely sensed data while advanced simulation and modelling technology produced various geospatial datasets to fill temporal and spatial gap of data coverage of the earth ecosystem research.

This module started by introduction of fundamental knowledge of ecosystem, followed by explanation of arid ecosystem and its importance of exist and ended the first part by introduction of global and regional ecosystem monitoring systems, network and technology. In the second part, application of remote sensing technology especially remote sensing detectable parameters and change detection technology, modelling of water cycling, carbon dynamics, simulation of hydrological process, extracting of precipitation, soil moisture, evapotranspiration and vegetation index etc. has been introduced using study cases in Central Asia and in China together with hand on practical exercises. Field data collection is crucial for model development and validation of modelled data. This module ended by suggestion of a virtual field work design on ArcGIS online and Google Earth via internet.

1.2 Learning Outcomes

- To have basic understandings of arid ecosystem and its importance of existence.
- To understand cutting edge technologies on remote sensing and GIS for monitoring of arid ecosystem in different scale of time and space.
- Able to collect geospatial data and models from internet for certain project.
- To understand theory and technology for Arid Ecosystem Modelling in space and time. Familiar with SWAT for ArcGIS.
- Able to design a system to geospatial support for arid ecosystem management.
- Able to use online high resolution satellite imageries (ArcGIS online, Google Earth, Google map) to collect surface parameters for developing model and validation of modelled data.

2. Module Structure

2.1 Module Overview

This module consists of 14 lessons with slides and accompanying notes, plus 2 to 4 required and recommended readings, 4 practical exercises and 5 self-assignments and a final project report and power point presentation as a final exam. The overall student effort for studying the core material is estimated at 160 hours. Most of the lessons equal to about 4 to 5 hours, excluding reading material, lab exercises and assignments. The module is intended to provide credit equivalent to 6 ECTS. The module materials are designed to be used flexibly, in either a traditional classroom setting or for on-line study.

2.2 Summary of Lesson Content

This section briefly presents the content and goals of each lesson.

- *Lesson 1: Understanding of Ecosystem* - This lesson will give a general introduction of ecosystem and its definition, classification, structure, functions and services and its relations to environment as well as ecosystem models.
- *Lesson 2: Understanding of Arid Ecosystem* – This lesson will introduce arid ecosystem and its distribution, importance of its existence through analysing of human history.
- *Lesson 3: Monitoring of Arid Ecosystem* –This lesson will introduce ecosystem monitoring systems and networks around the world and it is website. Student will learn which main parameters to be monitored is and how to monitor through reading introduction on the website.
- *Lesson 4: Remote Sensing for Arid Ecosystem Monitoring* –This lesson will introduce application of remote sensing technology on arid ecosystem research as Central Asia as example. Student will have general idea about how to design specific application of remote sensing in different environmental condition such as arid ecosystem. The general idea of example in this lesson should applicable in any other environmental conditions.
- *Lesson 5: Modelling of Water Cycling in Arid Ecosystem* - This lesson will focus on the models deal with water circulation in arid environment. 3 popular modeled will be used for the illustration by employs a case study in Tarim, namely SWAT, MIKE SHE and NAM.
- *Lesson 6: Precipitation* – This lesson will compare ground based measured precipitation data with satellite based precipitation data and employs a case study to introduce how to use multi-source data to generate and analysis precipitation in ecosystem.
- *Lesson 7: Soil Moisture* – This lesson will introduce concepts of soil moisture and it measuring tools including in site measurement and also satellite data. A case study of these data application will be introduced.
- *Lesson 8: Modelling of Evapotranspiration (ET)* - This lesson will demonstrate modelling of Evapotranspiration (ET) in arid regions of Xinjiang as a case study. Students will learn how to model ET by using Common Land Model (CoLM), and understand the framework of representations of ET processes in CoLM concerning root functioning. The detailed information about irrigation effects for cropland and root distributions associated with the root water uptake process and hydraulic redistribution for shrub land will be introduced.
- *Lesson 9: Modeling of Carbon Dynamics in Arid Ecosystem* - This lecture will demonstrate modelling of Carbon Cycling in an ecosystem of Central Asia as an example. Students will learn how to describe a key problem to be researched, how to select data and research methods, to for the discussion of the results and conclusion.

- *Lesson 10: Atmosphere CO2* – This lesson will introduce a case study to analysis spatial and temporal distribution characteristics of near-surface CO_2 concentration based on GOSAT and SCIAMACHY data. Spatial and temporal distribution characteristics of tropospheric CO_2 concentration based on AIRS data. Analysis of the influence factors of time-space distribution. CO_2 simulation base on GEOS-chem and Carbon Tracker.
- *Lesson 11: Drought monitoring* - This lesson will introduce how the drought defined, monitored, modelled and predicted by integrating different source of data by demonstrating a case study.
- *Lesson 12: Hydrological Process* - This lesson will introduce a modeling example of hydrological process for simulating. Key points are: The hydrological processes simulations in the arid mountainous basins, the spatial and temporal distribution of the climate change projections, the dynamic variation of water resources and its responses to climate change in arid mountainous river basins, the quantitative research about the impacts of climate factors changes on water resources.
- *Lesson 13: Climate factors and Vegetation Index* - This lesson will demonstrate how to monitor the vegetation changes by using remote sensing data, and its response to climate factors (precipitation and temperature). The grassland will be taken as an example, because it shows stronger sensitivity to climate change compared to other land cover types.
- *Lesson 14: Field work Virtual* - In this lesson recommend student to explorer a study area in 2D and 3D environment using ArcGIS online and Google Earth and to make a project map and living atlas on ArcGIS, finally using high resolution satellite imageries and 3D view to select sample site and measure some parameters such as vegetation coverage, slope aspect.
- *Lesson 15: Final project presentation and report* – In this concluding lesson, students present their own project to demonstrate how they used geospatial data and technology to support for Arid Ecosystem Management.

3. Hands-on Sessions

The module provides a number of interactive and hands-on activities to supplement the lecture content, deepen students' understanding, and develop their practical skills. Many of these activities are part of the module evaluation scheme.

- Visualize the Millennium Ecosystem Assessment data (Exercise)
- Analyze the trend of soil moisture ()
- To Simulate Evapotranspiration by Common Land Model
- Soil and Water Assessment Tool (SWAT) modelling

This module required basic skills of GIS software (ArcGIS, QGIS), and also some experience of using programming language such as R studio, Python etc. would be very helpful.

4. Teaching and Learning System

Classroom lectures, discussion and practice in laboratory and field stations will be introduced for understanding basic knowledge on arid ecosystem and its management. Hands-on practice of data collecting in the field and collect commercial and non-commercial (free data) geospatial data (satellite imageries and satellite based remote sensing data sets and products such as NDVI, DEM etc.) for ecosystem modelling and monitoring will be organized, and some existed Arid Ecosystem Model will be introduced by special practice. This module developed based on principles of distance learning or self-learning material, but it also can be used for classroom lecturing. In this case, there are three situations of learning environment. One is self-learning without internet access in rural area, second situation is self-learning with internet access, third is real or virtual classroom lecturing and face to face or online interactions. In all situations, student need to read the power point slides together with required readings carefully and recommended readings if possible. They also should do the exercises and assignments simultaneously with related lessons. In the end, student should make a presentation of his/her own project to demonstrate how geospatial technology implemented in their own project systematically and logically.

5. Evaluation System

The evaluation system consists of 4 assignments during learning period and an assignment as a final exam to present their own project. Assignments evaluation (out of 100 pts in total):

Assignment 1: Do presentation to demonstrate own understanding of Arid Ecosystem and its importance of existence. (15)
Assignment 2: To present a successful application of RS and GIS technology for Monitoring of Arid Ecosystem. (15)
Assignment 3: Success to build an ArcSWAT Model for a self-selected research area. (15)
Assignment 4: Design a field work for data collection for model development and result validation. (15)
Assignment 5(final exam): A presentation of own project to demonstrate Geospatial Support for Arid Ecosystem Management (40).

6. Additional Notes

This module need students already have basic understanding of geography, ecology, environment, ecosystem, remote sensing and GIS technology as well as some basic programming experience. However, if someone who did not have any experience with programming, it also possible to use this module for enriching their knowledge about how geospatial technology will support management of not only arid ecosystem but also all other ecosystem in the earth.

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