Extending Ground-Based Observations to Regional Scale : Multi-level Abstracted Landuse Class model

University of Bayreuth

KOREA FOREST RESEARCH INSTITUTE

Bumsuk Seo[1] and John Tenhunen[1*]

[1]: Department of Plant Ecology, University of Bayreuth, 95440 Bayreuth, Germany

Introduction

Background

Since land use significantly affects ecosystem landscape material balances and economically important outputs, there is a great need for spatial and temporal data on land use/land cover (LULC), although such data are often scarce or even impossible to obtain. Thus, a synthetic model of land use, which generates reasonable land use distributions from available covariates is extremely useful. Covariates, or related information exist in spatial databases, regional statistics and preceding (antecedent) research studies. In this context, we have designed a LULC model based on field mapping in a highland study area of South Korea (Haean Catchment). The specific goals of our work are (1) to derive a hierarchical structure describing the LULC realization process and (2) to derive and implement a LULC model across scales as described below.

Multi-level concept

Conceptually, we hypothesize that land use realization intrinsically has a multi-level structure, or hierarchy. According to our experience in the field, the realization of land use is not only made by a land owner's decision, but is affected or reinforced by many other factors. First, LULC is pre-determined by physical conditions and legal constraints. It has been thought that only economic expectations such as cost-benefit ratios are subsequent determinants, yet we realize that local heuristics matter in land use decision-making. Thus, we assume a step-by-step procedure from the bottom to top as shown in Figure 1.

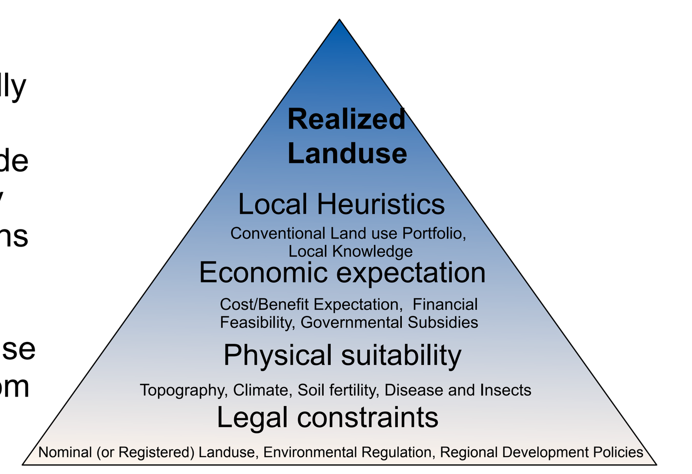
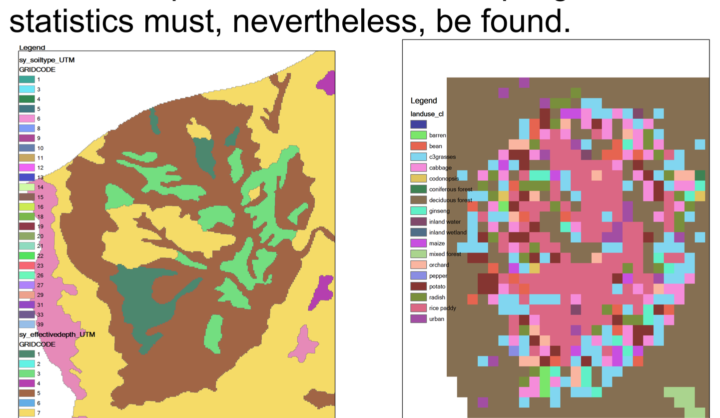


Fig.1. Multi-level concept to examine hierarchal structure in the landuse realization process. A step-by-step procedure from the bottom to the uppermost layer is assumed for simplification.

Problems Related to Scale

What is confronted after data acquisition is a scaling issue. By itself, the term 'scale' normally refers to spatial extent and temporal duration, but simultaneously a change in grain or resolution occurs. Scale differences among acquired covariates make synthesis of the data a delicate matter. For example, statistics often exist only at county level, rather than village or town level. Relationships between LULC sampling and these statistics must, nevertheless, be found.



a) Soil texture (Polygon) b) MODIS (250*250m)

Fig.2. Resolution discrepancy between a) soil texture map and b) MODIS sized grains of land use. Optimal grain size is greatly modified by the goals of a particular analysis. We do not attempt to obtain all data with the same grain, but find an appropriate scale for each analysis.

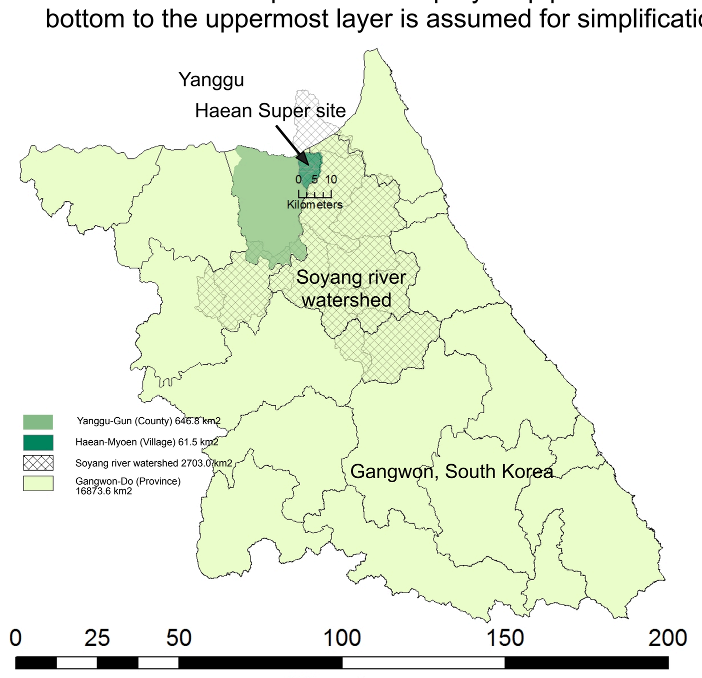


Fig.3. Geographic domain of the study area. Experiments and field survey have been pursued within the super site 'Haean Myeon', which is a small agricultural village sizes 61.5 km² while agricultural statistics are based on county-level data. Simulation modeling covers the bigger watershed called 'Soyang river watershed' which is not a jurisdictional unit yet most of the pre-existing databases built upon county or province basis.

Problems Related to Assessment of Ecosystem Services

Scale mismatch refers to resolution discrepancy as well as scope or extent. Most of the spatial data we collected are of coarse resolution, e.g. a 30 by 30m grid, while experimental plots are usually smaller. Not only spatial data but also statistics have their own scale, and these do not coincide. Nevertheless, we must carefully examine the characteristics of our data and specified scales, and potential ways to combine information. We attempt to interface phenomena that occur at very different scales of space and time via practical considerations together with simulation modelling. For example, regulatory agencies established a number of restrictions on farming practices to aid in solving the observed environmental problems at the watershed level, where fine scale and/or recent data is not available and cannot be collected. Regional simulation modeling to assess the consequences of these policies must consider the best compromises in representation of both processes and changes in LULC.

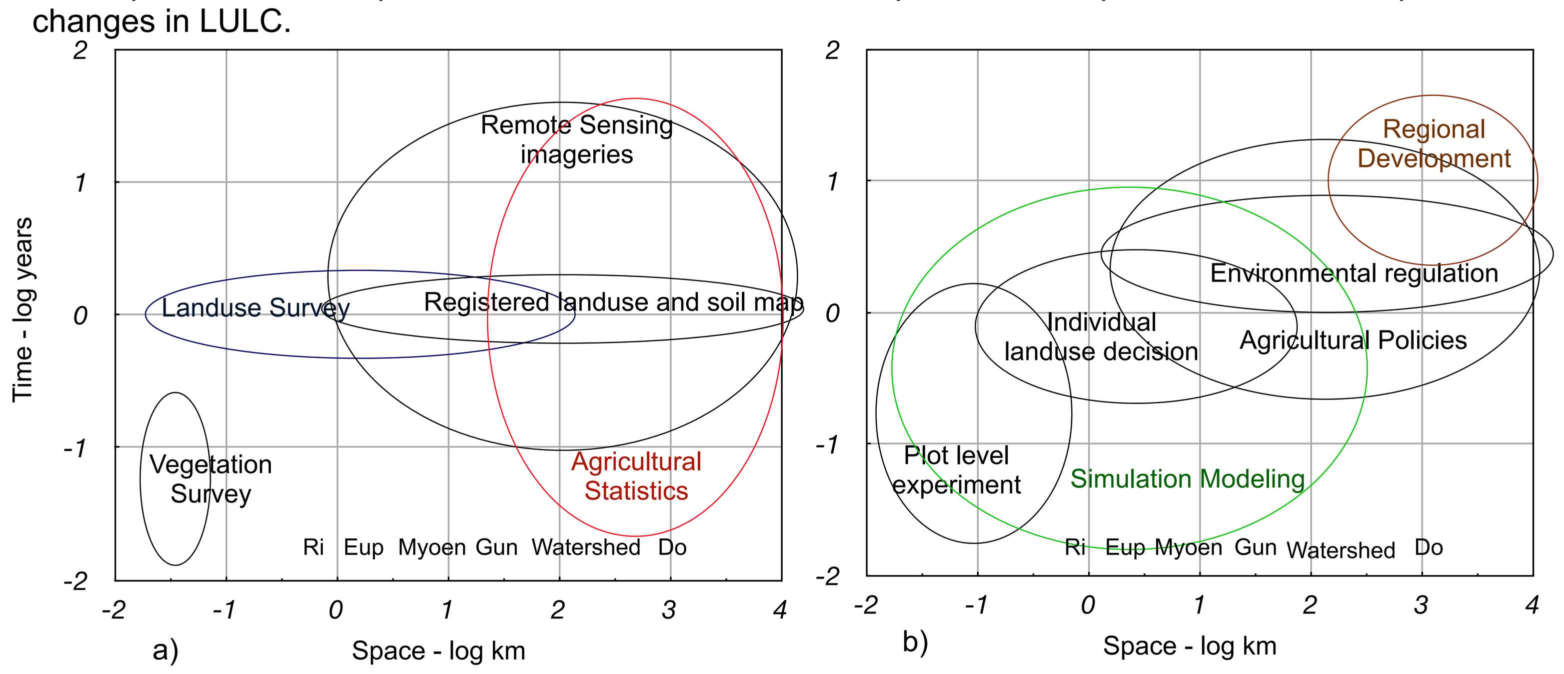
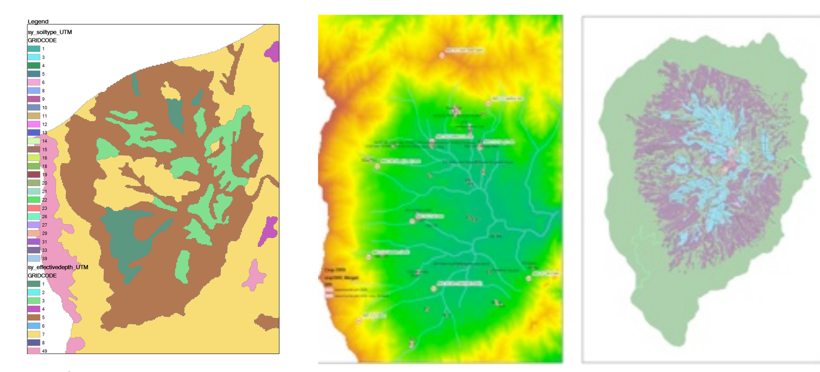


Fig.4. Temporal and spatial scales of a) the informational data and b) the related social-ecological processes in Soyang watershed. Activities spread over the scales temporally and spatially. It goes without saying that these are hard to capture at a single scale.

Data and Methods

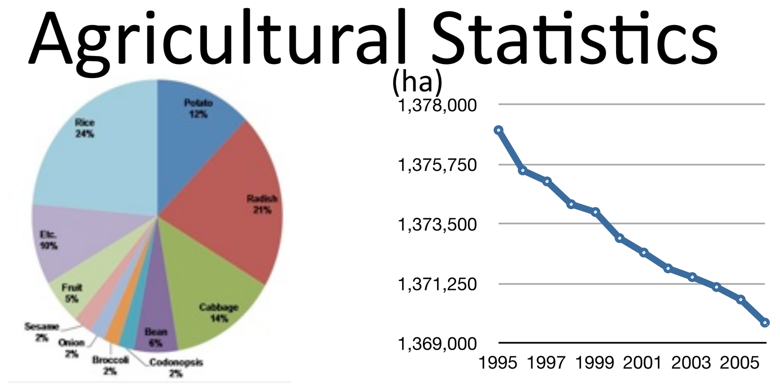
Spatial Database



a) Soil texture b) Topography c) Registered Landuse

Fig.5. Both at county and provincial scale, spatial databases are well archived and specified by the South Korean government. Existing spatial databases provide the landuse model with covariates as it underpins the realized landuse. On the other hand, they create a restriction or predetermine potential landuse where ground surveys are not available. e.g., Illegal to cultivate dryfield crop where registered (or nominal) landuse is rice paddy.

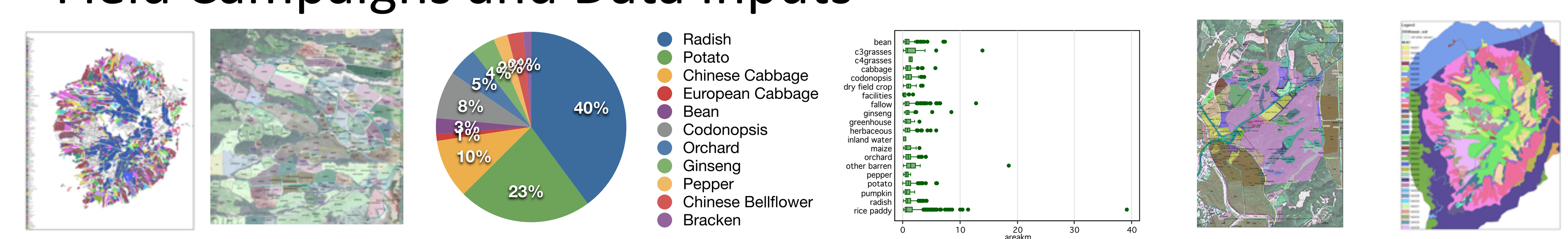
Agricultural Statistics



a) Crop production (County) b) Area of forest in Gangwon (Province)

Fig.7. A vast range of statistical data related to landuse is published by the South Korean government. Large-scale patterns and processes commonly can be identified at larger scale and data are often only available at the level. a) Crop production statistics for the county which contains our study site is in public domain since 1995. b) The percentage of forested area is decreasing steadily along with intensive development in Gangwon-do province.

Field Campaigns and Data Inputs



a) b) Landuse Survey (2007, 2009, 2010) c) Dry field farming composition (2007) d) Field Size distribution (2009) e) Field edge Samping f) Soil Survey

Fig.6. Various field campaign have been undertaken at the super site 'Haean', a small highland dry farming village. Detailed information was surveyed for all crop fields for 3 years and it covers more than 90% of the entire area. Several field edges are sampled intensively in 2010 to investigate non-crop plants. More than 200 soil samples have taken to extend the soil map obtained from the governmental database. Much additional research is underway to better understand available statistical data bases.

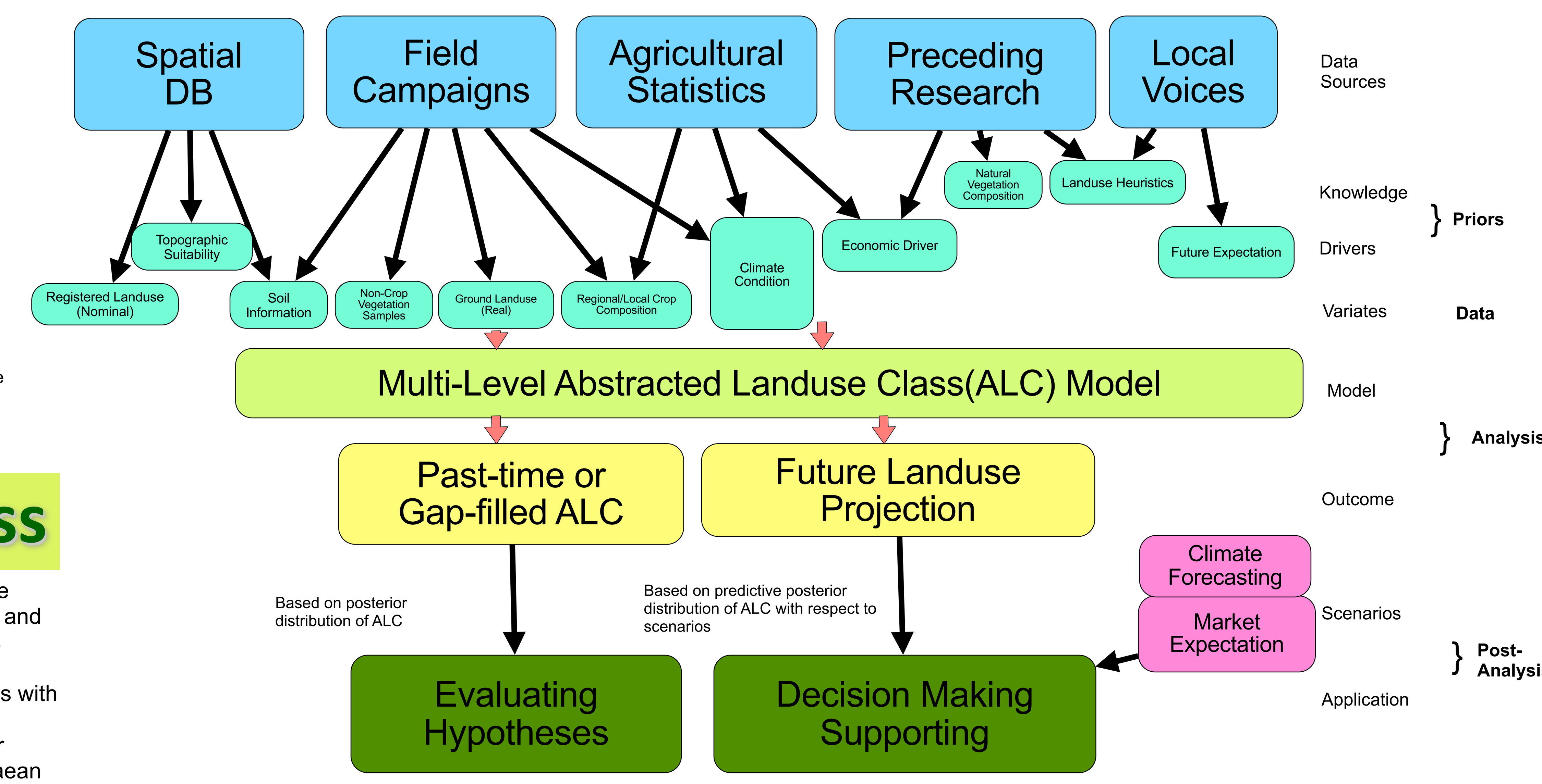


Fig.8. Scheme for developing LULC extrapolation tool. The blue boxes connote information related to input; these are categorized into three groups - Knowledge, Driver and Variate. Not only explicit covariates but also prior knowledge or experience are important in landuse decision-making as drviing forces. Bayesian techniques allow them to be incorporated into the probabilistic model. The ALC model extracts structural parameters from the multiple levels to depict the landuse realization process which is hierarchical in nature. Model outcomes as longitudinal ALC maps flow into regional simulations wherein we attempt to interface socio-ecological phenomena that occur at very different scales of space and time.

Abstracted Landuse Class

Abstracted Landuse Class connotes a lump of specific land uses which are grouped by their own functional characteristics. It is not feasible to identify and model every existing land use. Thus, we define the concept of ALC. At this moment, ALC classified landuse types are more or less based on physical functionality as agroecosystems, but also cover the most important aspects with respect to the local economic system. We propose that an intermediate complexity of class structure facilitates the incorporation of data from other scales. If correct, it will provide stronger predictive power outside of the Haean site, where ground landuse information is very scarce.

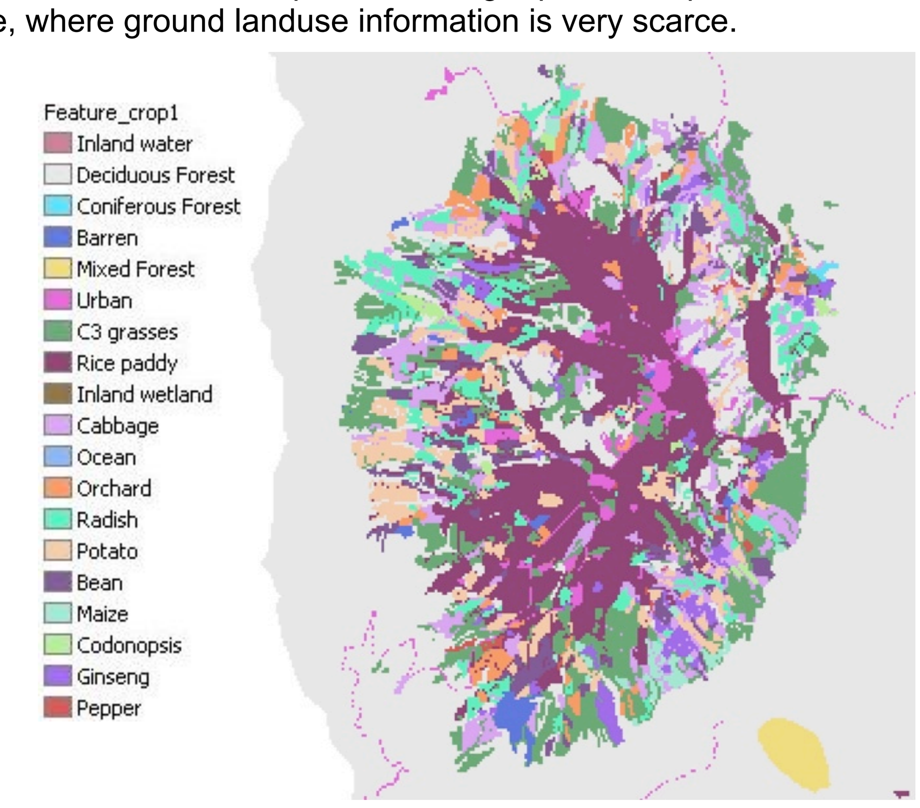


Fig.9. Abstracted Landuse Class based on functional grouping (2009)

Summary and Conclusion

The approaches in this study are oriented to combining data for land use extrapolation under scale considerations. In summing up, herein scale issue is viewed in two different points. First, we see a problem of scale as a technical issue. Data are distributed across scales, and we must recognize potential problems when we merge data of different scales. It is undertaken by deliberate investigation of the characteristics of data, and by using proper statistical techniques. In this sense, we make model input specified with its own scale as appropriate terminology. Spatial Bayesian statistics enables us to synthesize landuse in a proper manner. Secondly, the scale issue is examined in order to capture the best representation of socio-ecological processes. Cross-scale aspects of those processes call for a time-series landuse data over the larger scale, and it justifies why we develop a landuse extrapolation tool. What makes the long-term assessment of policies possible is an appropriate simulation modeling including variation in landuse, which has to be reasonably extrapolated. We have obtained an enormous amount of data in last few years, and hope to utilize the data in better way. This project is still in progress and one of the most important result expected is assessment of ecosystem-economic scenarios formulated with respect to global change issues: we believe landuse extrapolation is critical in this long journey.

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Contact

Department of Plant ecology, University of Bayreuth, Bayreuth, Germany

John Tenhunen:

john.tenhunen@uni-bayreuth.de

Bumsuk Seo:

Bumsuk.Seo@uni-bayreuth.de

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