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개발도상국에서의 통합자원관리연구에 관한 고찰
- 한국 지리학자의 역할과 GLOWA-Volta project에서의 경험 -

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Integrated resource management studies in developing countries: A Korean geographer's perspective and lessons from the GLOWA-Volta project

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요 약: 한국은 전세계적인 개발도상국 발전문제에 관한 논의에서 독특한 지위를 차지하고 있다. 그 특이성은 한국이 최근 국제원조의 수혜국에서 지원국으로 바뀐 것에서 잘 나타나며, 이것은 유래를 찾기 힘든 것이다. 경제가 발달함에 따라 한국이 국제사회에서 충분한 역할을 차지하기 위해서는 해외지역에 대한 보다 체계적인 이해와 지식이 무엇보다 요구된다. 이 글은 한국이 개발도상국 발달부분에서 새로운 지원국으로 등장함에 따라, 지리학자들의 역할이 무엇보다도 중요시 된다는 주장을 담고 있다. 한국 지리학자들이 기여할 수 있는 중요한 한 분야로, 빈곤문제의 해결과 개발도상국 발전에 기여할 수 있는 통합자원관리연구를 제시하였다. 개발도상국의 발전문제에 대한 전 세계적인 논의들의 변화를 약술하면서 통합자원관리의 중요성을 강조하였다. 통합자원관리연구에서 일반적으로 나타나는 세 가지의 문제점들 (스케일의 문제, 지식의 통합의 어려움, 그리고 의사소통의 문제)을 지적하였으며, 그러한 문제점을 극복해나가는 예를 현재 서아프리카의 가나에서 진행되고 있는 GLOWA-Volta연구에서 찾아 보았다. 결론으로 이러한 문제점들을 극복하는 데, 지리학자들이 가지고 있는 상대적인 이론적, 방법론적 장점들에 관해 기술해 보았다.

주요어: 한국, 개발도상국발전문제, 통합자원관리, 공적해외원조(ODA), 스케일, 학문의 통합

Abstract: South Korea occupies a unique position in world-wide development discussions, and its uniqueness is well exemplified by its recent shift from a recipient to a donor nation for international development aid programs. With increasing maturity of economy, knowledge and understanding about different regions is essential if Korea is to be a respected member of the international community. This paper contends that the emergence of Korea as an international donor requires more active responsibility from Korean geographers. This paper discussed integrated natural resource management (INRM) as a possible research agenda for Korean geographers as a contribution to Korea's role in world-wide poverty reduction and development of poor countries. This paper first summarized the recent changes in development philosophy, and emphasized the importance of INRM in developing countries. Three common problems (Problems of scale, integration, and communication) associated with INRM were discussed. Possible solutions to handle these problems were suggested based on an on-going research project in Ghana

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(GLOWA-Volta). As a conclusion, this paper discussed the comparative advantages of geographers for more active involvement both in development studies and INRM.

Keywords : South Korea, Development, Integrated Natural Resource Management, Oversea Development Aids (ODA), Scaling issues, Integration

I. INTRODUCTION

South Korea occupies a unique position in world-wide development debates. Harrison and Huntington(2001) made an interesting comparison between South Korea and Ghana in their book *Culture Matters*. In the 1960s, South Korea and Ghana, which have about the same-size territory with equally poor natural endowment, had a similarly developed economy. Forty years later, the economy of South Korea (Korea hereafter) has become 15 times larger than that of Ghana now being the 11th largest economy in the world, while the Ghanaian economy has remained almost unchanged over the last four decades〈Figure 1〉. The articles in the book offer various interpretations, ranging from 'global division of labor' to 'different social capitals'. The author' own opinion on these different development pathways between two countries will be reserved for future discussions, but he has recognized one significant implication from such comparison.

The uniqueness of Korea's economic and political development is well exemplified by its shift from a recipient to a donor nation for international development aid programs. With the increasing globalization of the world economy and the growing importance of global environmental issues, developed countries are obliged to support less-developed countries for humanitarian and socio-economic reasons. Korea, now a member of the Organization for Economic Co-operation and Development(OECD) is not an exception from this international responsibility. It is currently ranked as the 12th most important donor in the UN system, and its expenditure for oversea development aid(ODA) reached US$ 265 million in 2001(Table 1).

Compared with other developed countries, the current Korean ODA is low(Table 1). Symbolically, however, such financial contribution is

〈Figure 1〉 Comparison of economic growth in South Korea and Ghana

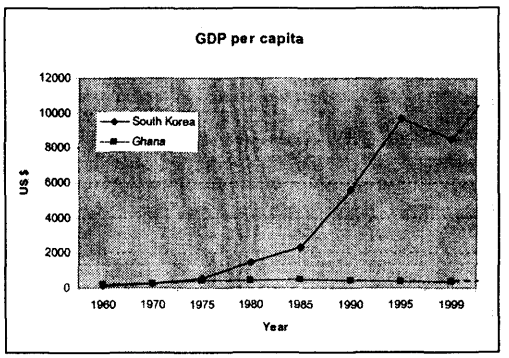


Table 1 Comparison of oversea development aid (ODA) among some selected OECD countries

Selected OECD countries	2001		2000		Change(%)
	ODA	ODA/GNI	ODA	ODA/GNI	
Australia	873	0.25	987	0.27	-4.0
Austria	533	0.29	423	0.23	27.3
Belgium	867	0.37	820	0.36	6.9
Canada	1,533	0.22	1,744	0.25	-9.4
Denmark	1,634	1.03	1,664	1.06	-1.6
France	4,198	0.32	4,105	0.32	3.6
Germany	4,990	0.27	5,300	0.27	0.8
Italy	1,627	0.15	1,376	0.13	18.6
Japan	9,847	0.23	13,508	0.28	-16.6
Netherlands	3,172	0.82	3,135	0.84	-0.5
Norway	1,346	0.83	1,264	0.8	6.8
Spain	1,737	0.3	1,195	0.22	43.9
Sweden	1,666	0.81	1,799	0.8	2.4
Switzerland	908	0.34	890	0.34	0.1
United Kingdom	4,579	0.32	4,501	0.32	4.4
United States	11,429	0.11	9,955	0.1	12.4
Total DAC (22 countries)	52336	0.22	53734	0.22	0.5
South Korea	**265**	**0.06**	**212**	**0.05**	**40.5**

unprecedented : 'A country once benefited from the world communities now pays back to other less fortunate countries'. Table 1 further suggests that Korea's contribution to ODA may increase rapidly in near future. The OECD organizes a Development Aid Committee(DAC) among its member countries. The DAC encourages its member states to contribute to world-wide equal and sustainable development by providing technological and financial support to developing countries. Among OECD countries, Korea is one of few countries that are not currently registered as a member of the DAC, and is spending only 0.06 % of its Gross National Income(GNI) on foreign aid. This figure is well below the average expenditure(0.22 % of GNI in 2001) of all DAC countries and the 0.7 % of GNI recommended by the UN. With increasing maturity of the Korean economy, the governmental and private sectors will soon face strong demands to meet the standard set by the world communities.

As not so long ago Korea was a recipient

country, ODA is a rather unfamiliar concept to many Koreans. Some Koreans believe it is more important to solve domestic poverty problems than to spend money on other countries(KOICA, 2001). It is extremely important, however, to consider ODA as a long-term investment rather than short-term expenditure. Considering the fact that the rapid development of the Korean economy has mainly been export-driven, promoting economic growth in neighboring countries certainly helps foster economic and political stability, and expand future trade and investment opportunities. This is especially imperative considering the fact that a large portion of the world's poverty is located in the Asia-Pacific regions. Recent World Bank statistics shows that 1.3 billion people over the world survive on less than a dollar a day, and half of them are in the Asia-Pacific regions(World Bank, 2001). The vivid memory of the Asian financial crises well exemplifies the importance of regional economic stability and the necessity for more detailed understanding in this region. Korea's current economic development policy aims to make it one of the leading states in far east Asia, which obviously calls for active responsibility as far as regional matters are concerned.

The possible increase in Korea's ODA contribution requires more urgent discussions on 'wiser' use of aid. The author contends that the emergence of Korea as an international donor nation requires more active responsibility from Korean geographers. Geography has traditionally been considered as a science focusing on regional studies, and the development of geography in many developed countries has been closely linked with studies in foreign regions(Pattison, 1964). The objective of this paper is to discuss integrated natural resource management(INRM) as a possible research agenda for Korean geographers as a contribution to Korea's role in world-wide poverty reduction and development of poor countries. This paper first summarizes the recent changes in development philosophy (section 2), and emphasizes the importance of INRM in developing countries(section 3). Section 3 identifies three common problems associated with INRM. Section 4 is a brief explanation to demonstrate the author's experience in handling these problems based on an on-going research project in Ghana(GLOWA-Volta). As a conclusion, section 5 contains some recommendations for Korean geographers concerning more active involvement both in development studies and INRM.

II. NEW PARADIGMS IN INTERNATIONAL DEVELOPMENT

The development is an extremely complex matter, which has been interpreted by many contrasting theories(Peet and Hartwick, 1999; Potter et al., 1999). In the 1990s, international communities observed significant changes in

international development philosophy. The collapse of the former Soviet Union, the increasing importance of global environmental issues, and the accumulated experience of development in different countries brought in significant changes in thinking about the way development works(Staatz and Eicher, 1998).

The recent World Development Report summarizes the shift of development paradigms during the last 50 years(World Bank, 2001). In the 1950s and 1960s, many viewed large investments in physical capital and infrastructure as the primary means of development. In the 1970s, awareness grew that physical capital was not enough, and improvements in health and education were important not only in their own right but also for promoting growth in the incomes of poor people. The 1980s saw another shift of emphasis following the debt crisis and global recession and the contrasting experiences of East Asia and Latin America, South Asia, and Sub-Saharan Africa. Emphasis was placed on improving economic management and allowing greater play for market forces. Consequently, the development agency promoted labor-intensive growth through economic openness and investment in infrastructure and by providing basic health and education services to poor people. Based on the earlier strategies and cumulative experience, the World Bank put forward three key strategies to attack poverty in the year 2000: promoting opportunities, facilitating empowerment, and enhancing security (World Bank, 2001, pp.6-7).

Promoting opportunities requires actions by the state and international communities to provide more opportunities for poor people to improve their quality of live. Such opportunities include jobs, credit, roads, electricity, markets for their products, schools, and water, sanitation, and health services. Facilitating empowerment indicates the widening of the choice and implementation of public actions that are responsive to the needs of poor people depend on the interaction of political, social, and other institutional processes. This requires 1) strengthening the participation of poor people in political processes and local decision-making and, at the same time, 2) removing the social and institutional barriers that result from distinctions of gender, ethnicity, and social status. Enhancing security is reducing vulnerability-to economic shocks, natural disasters, ill health, disability, and personal violence. In order to reduce people's vulnerability, 1) the nation should manage the risk of economy-wide shocks and provide effective mechanisms to reduce the risks, and 2) poor people should build their own assets by diversifying household activities and providing a range of insurance mechanisms to cope with adverse shocks.

This summary clearly indicates that the main emphasis of development aid should be on providing adequate political-social-economic environments and human capacity building, rather on supporting uni-directional infrastructure

projects and direct poverty relief activities. Therefore, promoting economic growth only is no longer considered as the main aspect of development(Potter et al., 1999). Economic growth should be accompanied by human development that includes improving people's knowledge and skills in addition to the improving the socio-economic conditions that support such practical assistance(UNDP, 1996).

1) Capacity building and reducing knowledge gaps

One of main stumbling blocks for both economic and human development is the lack of knowledge in many developing countries. With the development and growing use of information technologies, the distribution of knowledge has become much more efficient in the developed countries. The majority of developing countries, however, are a long way away from this kind of immediate access to information. Consequently, poor people cannot access appropriate knowledge even though it is widely available in other parts of the world. Many believe this knowledge gap is the main limitation for development and may further increase the difference between developed and developing countries(World Bank, 1999).

Development is an extremely complex issue and the reasons for poverty are very diverse. Understanding generated in the past is often inadequate for solving present problems. This is especially the case with the current rapid economical globalization and environmental uncertainty(ZEF, 2002). Furthermore, the experience and success gained in one area is not easily transferable to other areas due to the diversity and complexity of the causal relationships underlying poor development. Solving local development issues calls for a variety of skills so that scientists and policy-makers can focus on real global problems, and requires insights into complex local, national, regional, and international dynamics. As democratization and more open market economies spread, decisions on how to resolve problems of development will involve more decision-makers than ever before.

Most developing countries suffer a shortage of researchers and policy-makers who are able to understand and address such complexities and diversities associated with poor economic development. In recognition of these problems, world development communities put a strong emphasis on narrowing the knowledge gap between rich and poor nations as the center of development aid strategies. In a recent World Development Report(World Bank, 1999), the World Bank urges developed countries to support efforts by developing countries to increase their capacities to acquire, absorb, create and utilize knowledge, thus enabling them to achieve knowledge-based sustainable economic development. At the same time, developing

countries should attract and train talented individuals and provide them with the support needed to conduct problem-solving research (ZEF, 2002).

2) Sustainable development

The second shift in the development agenda comes from the merge of development issues with ecological sustainability(WCED, 1987; Staatz and Eicher, 1998; Pinstrup-Anderson et al., 1999). The 1990s witnessed a rapid increase of global concerns on transboundary environmental issues, such as global warming, biodiversity loss, and depletion of the ozone layer. People have recognized that many regional or local environmental problems, such as urban degradation, deforestation, desertification, or water or fuel wood scarcity, are of significant transboundary nature and directly influence the global environmental changes(Hurrell and Kingsbury 1992). In several high-profile discussions, including the Rio Summit 1992, and the Kyto Protocol 1994, those environmental issues were no longer viewed as being merely scientific and technical problems, but as being the central issue in world development policies (Chasek, 2000). Consequently, concern for the sustainability of the Earth led to significant changes in environmental management both in developed and developing countries(Pinstrup-Anderson et al., 1999).

The implication of the emergence of the sustainable development issue is particularly acute for many poor people in developing countries(WCED, 1987). As their economic structure is tied to agriculture, forestry and rural areas, dependency on natural resources is extremely high in most developing countries. The world poverty map also shows that many developing countries are located in ecologically vulnerable areas. Many argue that short-term economic growth often undermines the long-term productivity of natural resources and the environment. The ever-increasing population pressure and the lack of adequate technological inputs result in rapid soil degradation and the conversion of forest to agricultural lands (Stoorvogel and Smaling, 1990; Pinstrup-Anderson et al., 1999). The implication of such natural resource exploitation in developing countries is now projected from the viewpoint of the global environmental issues, and their solution will thus require a global effort that involves all sectors of society - including the participation of highly skilled and motivated scientists in both advanced and developing countries. Consequently, there is a necessity for more active involvement of developed countries in local environmental management issues in developing countries, who do not have sufficient technological and natural resources to maintain environmental sustainability(ZEF, 2002; World Bank, 2002).

Ⅲ. INTEGRATED RESOURCE MANAGEMENT RESEARCH AND ITS METHODOLOGICAL CHALLENGES

The emphasis of knowledge-based human development and the issues of sustainable environments brought natural resource management to the forefront of world development issues(World Bank, 2002). One particularly interesting change is the introduction of integrated natural resource management (INRM). The issues of development have complex dimensions, which include cultural and social factors, institutional and technological innovations, and complex ecological issues. Until the 1970s, environmental conservation, food security, and rural economic advances were treated as largely independent sectors of research and development(Staatz and Eicher, 1998; ZEF, 2002). Local farmers frequently fail to adopt the development of an agronomic technology due to the lack of understanding on the part of the researchers concerning the farmers' cultural and economical constraints. The extensive economic advice given by international communities has often failed due to the limited understanding of the natural and environmental constraints at the local level(ZEF, 2002).

The poor outcomes of sector-oriented approaches catalyzed efforts to address environmental and socio-economic problems concurrently. These approaches, commonly referred to as integrated natural resource management research(INRM), emphasize the appropriate integration of socio-economic, biophysical and institutional knowledge for specific land management(Dumanski and Craswell, 1998; Pinstrup-Anderson et al., 1999). INRM is also perceived as the central methodological framework for combating poverty in many developing countries, as it combines ecological sustainability and participatory approaches. It aims to help people understand and manage the complexity of rural livelihoods through integrated and holistic analysis(Pinstrup-Anderson et al., 1999).

The fundamental constraint for the success of INRM is the extreme heterogeneity of socio-economic and natural resource conditions at local, regional, and global levels(Carter, 1997). Natural resources, including soils, climate, topography and vegetation, are highly diverse both in space and time. The same applies to socio-economic and cultural factors, such as population pressure, infrastructure development, and land tenure. It becomes clear that sustainable natural resource management can only be successful if broad recommendations at the national level are integrated into fine-tuned policies at local levels, where specific natural resource, socio-economic and cultural conditions prevail(Wood and Pardey, 1998; Rykiel, 2000). Such spatial and temporal variability has led to

important methodological and practical constraints for integrated resource management frameworks, which may be summarized in this paper as problems of scale, integration, and communication.

1) Problems of scale

Any INRM should be preceded by the identification of patterns and processes involved in natural resource management(Carter, 1997; Wood and Pardey, 1998). What is the dominant land-use types in the targeted area? What are the major ecological constraints? What influences the choice of specific land management? The identification of patterns and processes is often determined by the spatial, temporal, and measurement scales chosen to investigate heterogeneous landscapes(Kirkby et al., 1996; Gibson et al., 1998). In a statistical modeling attempt to characterize the land-use-change patterns in a 100 km by 100 km area in Ghana during the last 20 years, Park et al.(2003) first observed that there was virtually no significant spatial correlation between land-use change intensity and various land-use change dynamic predictors(e.g., distance from road network, population density, distance from fresh water, and topography). However, when they applied a multi-scale adaptive model in which land-use change intensity was regressed against dependent variables within a moving window, highly disaggregated spatial patterns of environmental correlation appeared over the study area.

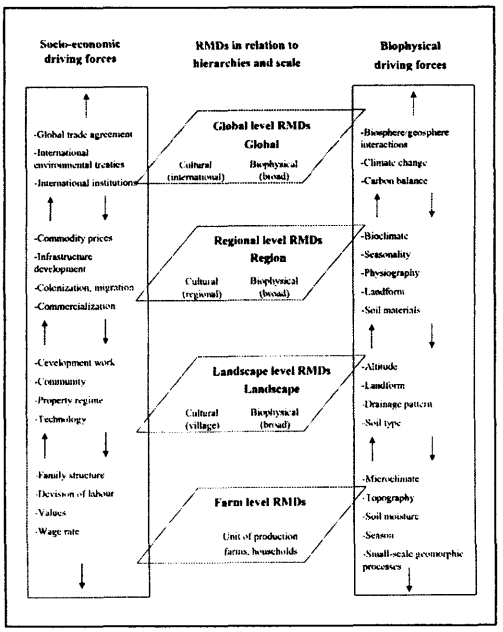
They observed that high spatial associations between the land-cover change index and environmental variables were mostly limited to a spatial scale less than 10km because of the heterogeneity of human-nature interactions. With increasing spatial coverage within the regression model, land-use change processes within the window turned out to be too diverse to establish clear trends. Therefore, changes in one part of the window were compensated elsewhere, which resulted in a reduced R^2 between land use change predictors and land-cover change index. They contend that ignoring such spatial heterogeneity and scale effects would result in either over- or underestimating the significance of land management processes over the landscape, and policy makers would be misled when deciding on the best site-specific policy intervention.

The change of scale is directly linked with the changes of dominant system components and interactions(Kirkby et al., 1996; Schulze, 2000). For an individual field, a farmer's land management might be the dominant process that determines soil quality. However, if one considers the hillslope as the management unit, then topography might become more important to explain the variation of soil quality. If the regional scale is considered, we expect that the dominance of topography as the main variance generator for soil quality could be gradually replaced by other environmental factors, such as

parent material, regional climate, or geology. Similar changes concerning dominant processes along the spatial extent have been also recognized in socio-economic conditions(Turner II et al., 1994; Dumanski and Craswell, 1998). Family structure and division of labor may be the most important factors for resource management at the farm level, but infrastructure, commodity prices and commercialization might dominate socio-economic conditions at the regional level. 〈Figure 2〉 summarizes the scale dependence of the main variance components for both biophysical and socio-economic conditions.

It is commonly acknowledged that the only way to capture scale-dependent spatial processes is to make correct observations at the scales at which the processes and physical laws are taking place (Becker and Braun, 1999; Schulze, 2000). However, for the majority of cases, available databases are limited to a much smaller spatial scale than the scale at which actual processes occur. Many countries have generated small-scale national databases(mostly at a coarser than 1:1,000,000), but the adequacy and quality of those spatial data for practical purposes are often limited(Carter, 1997; Wood and Pardey, 1998). This problem is particularly severe for socio-economic spatial information. Most of the socio-economic information is only available in a spatially aggregated form(such as district or regional level) or in a limited area where intensive surveys have been conducted.

〈Figure 2〉 Scale dependency, and dominant factors and processes for spatial variability of biophysical and socio-economic conditions relevant for natural resource management (Dumanski and Craswell, 1998)



The limitation of data availability at sufficient detail has been causing various scaling issues: estimates on-going processes from observations on a small spatial(or temporal) scale to observations on larger scales(upscaling), or moving from large-scale observation to smaller scales(downscaling). Recent work on the scaling behavior of various phenomena and processes (including research in global changes) has shown that many processes do not scale linearly(Kirkby et al., 1996; Becker and Braun, 1999). Another difficulty associated with scaling is the 'emergence' (Gibson et al., 1998). The smaller scale properties often combine together and generate a new or unexpected phenomena.

Numerous cells containing different biological functions, join together to form a human body that has consciousness. Individual human beings again gather together and form communities and villages, which often show unique collective actions.

2) Problems of integration

Once the patterns and processes related to natural resource management have been identified, the next methodological challenge is how to integrate them into a systematic framework. Elements in a natural and socio-economic system respond nonlinearly at different scales, according to different thresholds and lags, and with varying degrees of feedback(Becker and Braun, 1999). As an example, one can easily assume that the soil quality shows different spatial patterns with changes in agro-climatic conditions. The decision-making processes of local farmers may also change based on their cultural heritages and economic assets. Questions that might come up for policy makers in that context could be: What will be the results of the interactions between two different systems? How does soil quality interact with the farmer's decision on which land management to apply? How do the farmer's specific socio-economic conditions influence on his land management decisions? Conventional analyses have addressed one or more issues in an isolated manner, but the interactions among individual systems has rarely been analyzed in an integrated manner (Dumanski and Craswell, 1998).

Two distinct approaches might possibly identify such interactions: process models and empirical models (Irwin and Geogehgan, 2001). Empirical models attempt to determine functional relationships between model components using either an existing or a specially designed field survey. Statistical models are generally used to characterize such functional relationships. Technologically, empirical models are relatively simple to build/develop, but these models cannot take account of temporal changes of potential interactions between natural and economic conditions. The diversity or heterogeneity of natural resources related to the interaction is often considered as 'noise' of a general trend within the spatial and temporal boundaries. Consequently, important localized processes are often 'smoothened' by statistical models (Brunsdon et al., 1996; Park et al., 2003). Furthermore, the derived functional equation is locally specific, and is thus difficult to extrapolate to other areas unless environmental conditions are similar.

Process-based modeling approaches are built on mathematical equations to quantitatively model possible interactions between model components connected to resource management processes (Aggarwal et al., 2002; Stephens and Matthews, 2002). Since process models explicitly include socio-economic constraints and ecological

processes, these models are supposed to be able to simulate both temporal and spatial dynamics of resource management. Consequently, the ability to include temporal changes and spatial heterogeneity of natural conditions is much higher than in the case of empirical models.

While processes-based modeling approaches are often preferred over empirical ones, the high demands of technological sophistication and heavy calibration-verification procedures are the main limiting factors for a wider application (Stephens and Middleton, 2002). Especially when models are used for natural resource-related decision-making processes, it is essential to include a wide range of input options that are relevant to policy and agriculture questions (Stephens and Middleton, 2002). Such calibration and verification issues are especially problematic for developing countries, where necessary technological and financial resources are not easily available. Therefore parameterization often comes from previous research conducted in different environmental conditions or from expert opinions. The uncertainty associated with such parameterization will greatly increase the validity of model outputs and the reliability of model application(Penning de Vries et al., 1989; Aggarwal et al., 2002; Stephens and Middleton, 2002).

3) Problems of communication

INRM aims to include not only various academic disciplines, but also various stakeholders (farmers, faming communities, NGOs, and states) in their methodological procedures. Consequently, intensive dialogues are essential to build a relevant INRM framework. The difficulties during such dialogues often arise at different levels; 1) between scientists and policy makers, 2) among scientific disciplines, and 3) between scientists and local stakeholders.

(1) Communication between scientists and policy makers

There has always been large discrepancy between 'value-neutral' science and 'value-laden' policy(Rykiel, 2000). Scientists often consider their professional responsibility is keeping their objectivity associated with the output of their professional activities. Science can delineate the possibilities and describe the system that is likely to result from a policy, but it cannot decide if the resulting system is good or bad. This is often incompatible with the fact that value judgments are the essence of decision-making processes in policy arenas. Policy makers often want to see immediate impact of the policy outputs; this behavior is based on a ruler that measures whether the introduced scientific policy is good or bad for society.

(2) Communication among scientific disciplines

Many scientists and policy makers involved in INRM often observe great differences in work ethics, methodological approaches, and use of terminologies among different disciplines(Berger et al., 2002). For socio-economists, for example, the main unit of observation is the individual household. Here, research focuses on understanding the households' choices among feasible alternatives of action and in particular on their strategies for coping with various environmental challenges. Political scientists focus on decision-making processes dealing with the same issues at higher levels of social organization. For these scientists, the unit of observation is thus not the single household, but the village assembly, the water user association, etc. However, hydrologists and soil scientists use research units that are related to landscape boundaries rather than social entities. The hydrologists undertake their research in small, experimental watersheds(1-10km^2). Soil scientists and geographers focus on landscape units that are grouped into different land-use and land-cover classes. All those scientists also often adopt varying degrees of complexity in their methodological framework. These differences come from their educational backgrounds, and are often enhanced as their academic careers that are frequently determined by acknowledgement from their own disciplines, notably in form of scientific publications(Berger et al., 2002).

(3) Communication between scientists and stakeholders

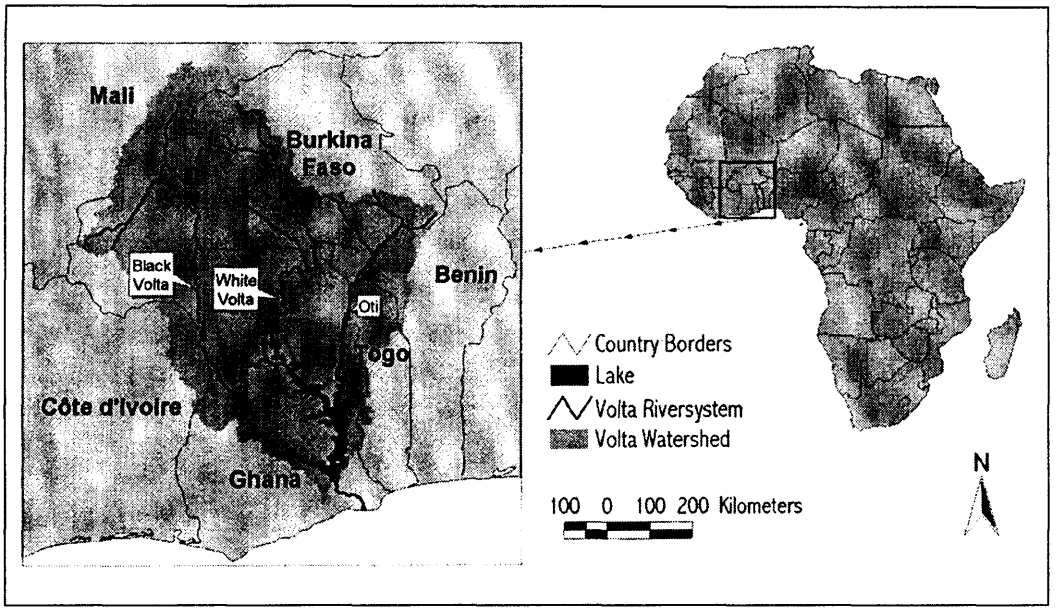
One of the main barriers limiting the adoption of science-based knowledge in INRM is the lack of knowledge on the part of the farmers or their unwillingness to adopt the knowledge provided by scientists. The low adoption rate is also often caused by inadequate consideration of the local conditions. Natural resource specialists often do not understand the human history of regions, nor do they understand and appreciate how cultures and ecosystems evolve, or possess enough humility to keep searching even after they think they know enough(Vlek et al., 2003). At the same time, recent research suggests that many smallholder farmers already know of the spatial distribution of farming constraints over the landscape based on their own long-term farming experience. Their understanding is accurate enough for further modeling attempts(Brunner et al., 2002). However, farmers often fail to utilize their knowledge for more sustainable land management, due to the lack of knowledge on feasible land management options and also because of various social-economic constraints. Appropriate communication between local stakeholders and scientists is the first step to reduce for developing methodology under the INRM framework.

Ⅳ. HOW TO INTEGRATE THEM: EXPERIENCE FROM THE GLOWA-VOLTA PROJECT

GLOWA, a German acronym for Global Change and the Hydrological Cycle, seeks to develop simulation tools(Decision Support System, DSS), that allow the design and implementation of strategies for sustainable and future-oriented water management at the regional level (approximately 100,000km^2) (Vlek et al., 2003). The uncertainty of water availability in a rapidly developing global environment jeopardizes the survival of many people. The German Federal Ministry of Education and Research(BMBF) initiated the GLOWA program in 2000 to tackle such uncertainties under the framework of INRM. The objective is to predict the impact of global changes, both environmental and social, on all aspects of water availability and use. Five projects are underway within the GLOWA program, which are studying a total of six watersheds, aligned more or less along a north-south gradient. The rivers Elbe and Danube in Germany, Draa and Jordan in the Mediterranean region, and Oueme and Volta in West Africa(www.glowa-volta.de).

The watershed of the Volta is one of the poorest

〈Figure 3〉 Overview of the Volta Basin (from Vlek et al., 2003)

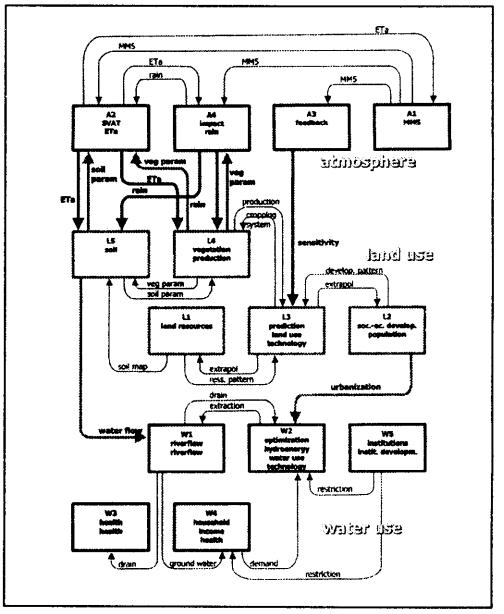


areas of Africa. Average annual per capita income is about US $600 per year. The basin covers 400,000 km² with 42% in Ghana, 43% in Burkina Faso and the remainder in the Cote d'Ivoire, Mali, Togo, and Benin〈Figure 3〉. Rainfed and some sections of irrigated agriculture are the backbone of the largely rural societies and the principle source of income. Population growth rates exceed 2.5%, placing increasing pressure on land and water resources and driving a rapid urbanization process. Improved agricultural production in the West African savanna depends on the development of (near)surface water resources and their effective use(van de Giesen et al., 2001). Precipitation in the region is characterized by large variability, as expressed in periodic droughts. Unpredictable rainfall is a major factor in the economic feasibility of hydraulic development schemes, as witnessed by the major 1984 drought and the power shortages that plagued Ghana in 1998. Early results from the GLOWA Volta project show that changing land use and land cover is the main global change phenomenon within the basin(van de Giesen et al., 2001).

To understand all aspects of the hydrological cycle in the Volta Basin, one needs to take all bio-physical(atmosphere, land, water) and social aspects(population, economic development, institutions) into account. Integration of ecological, climatic, and socio-economic factors and their interactions with respect to the hydrologic cycle in the GLOWA Volta Project aims at the development of a Decision Support System(DSS) for the basin-wide management of water resources. The dynamics are addressed by fourteen sub-projects that are grouped into three research clusters: atmosphere, land-use change, and water use(see Vlek et al., 2003 for further details). 〈Figure 4〉 shows how the different sub-projects are connected and also where information concerning the different key variables of the DSS will be produced.

Here the common problems recognized in INRM(section 3) will be addressed, based on the author's experience under the framework of the GLOWA-Volta program.

〈Figure 4〉 Cluster and subproject structure of GLOWA Volta project (from Vlek et al., 2003)



1) Problems of scale

The major challenges of the GLOWA-Volta project were how to characterize the extreme complexity of the main factors involved in water availability within the basin, which spreads over a large area, and to harmonize different research disciplines to achieve the proposed goals in a scale-sensitive framework. Continuous multidisciplinary discussions have created a new methodological framework〈Figure 5〉, which ensures a maximum overlap not only between socio-economic and biophysical field observations, but also between different observation scales of individual subprojects.

The methodological framework for capturing the spatial variability comprises three research activities: a 'common sampling frame', intensive field experiments, and cross-scale linkages. 'The common sampling frame' was developed to increase reliability of socio-economic and natural resource surveys to allow generalization of the findings at the local level to the national and basin level. Accommodating different specific research objectives and methodologies used in different disciplines, a hierarchical sampling frame was developed. This sampling framework is based on a statistical representation of the whole of Ghana using the Ghana Living Standards Survey and publicly available geospatial information(see

〈Figure 5〉 Methodological framework for explaining cross-scale linkage between basin-wide investigations and detailed calibration studies at the experimental catchment. Please note that the subproject notation follows the phase I of the GLOWA-Volta program availasle from www.glowa-volta.de

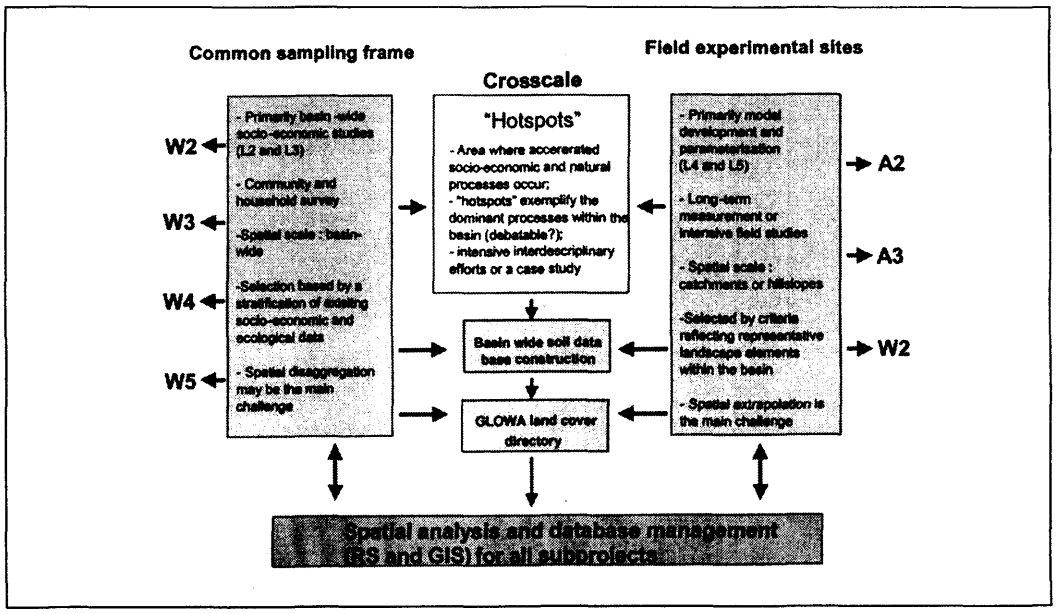


Table 2 Objectives and observation units of different academic disciplines under the framework of a common sampling framework (from Vlek et al., 2003)

Discipline	Research activity and observation unit	Purpose
Geography	Land cover recording chart of Community landscape	Ground-truthing of remote-sensing images
Political sciences, anthropology	In-depth interviews with village elders; household interviews	Institutional analysis
Economics	Household interviews	Household water demand; Migration behavior
Agricultural Economics	Household interviews	Water and land-use decisions
Soil sciences	Plot survey	Soil quality analysis
Hydrology	Bacteriological analysis of water	Water quality analysis

publicly available geospatial information(see Berger et al. 2002 for detailed procedures). Based on this sampling scheme, different scientists involved in each discipline harmonized the field survey including land-cover classification, socio-economic household survey, soil quality assessment, and water samples(Table 2).

On the other hand, the proposed DSS requires reliable meteorological, hydrological, socio-economic and land-use change models to simulate the impact of specific decision making. All these models require detailed parameterization procedures, which can be only achieved by long-term monitoring and field experiments. Therefore, detailed field experiments on soil and hydrological processes are being carried out in three experimental sites. The sites for the experiments were chosen based on agro-ecological and socio-economic conditions, which are overlapped with the areas selected for the common sampling framework.

In order to ensure scaling linkage between basin(nation)-wide investigation and detailed experiments at the experimental catchments, several 'cross-linkage' activities were implemented. These include 'basin-wide soil data base construction', standard land-use classification, and development of algorithms to investigate the spatial dependency of the spatial data set. Remote sensing(RS) and Geographical Information System (GIS) will be efficient tools to bridge these two different spatial scales of the field investigations. In addition to the comparison of various existing scaling methods and the development of a new

investigate covariance structures that might exist among different GIS and RS information layers. It is not correct to assume that all these data are spatially independent. As an example, vegetation intensity derived from RS images has shown strong correlation with topographical factors; the correlation changed over the season, possibly due to the changes of hydrological conditions. Adequate understanding of such covariance structure and its scale dependency may greatly reduce time and efforts to collect separate spatial information to satisfy the demands for input parameters. A major achievement is the development of a scale-sensitive statistical technique to identify the covariance structure of various environmental variables(Park et al., 2003).

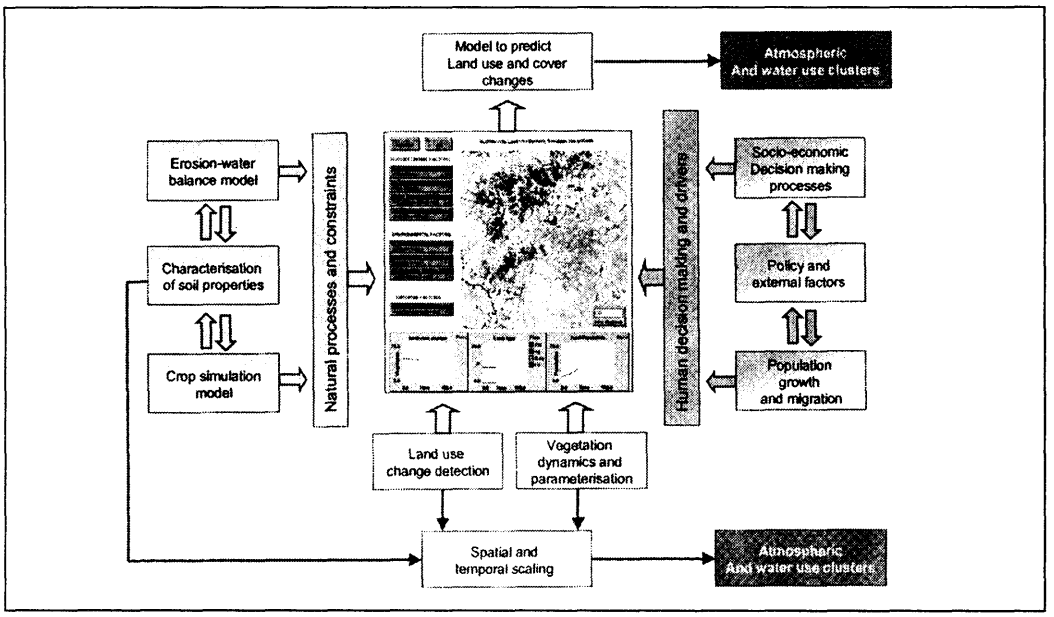
2) Problems of integration

In total, there are fourteen subprojects in the GLOWA-Volta project in three groups (atmosphere, land use, and water use). Integration of these individual research components and the involved scientists has been a major challenge. In the first phase of the project(2000-2003), scientists have concentrated mainly on conceptual integration or, in other words, on the development of new methods of coordinated data gathering and modeling. The idea was that by concentrating on integration in few focal points at the conceptual level, it would be easier to define precise goals and to make progress with small interdisciplinary teams(Vlek et al., 2003). Based on discussions, the subprojects were regrouped as three foci in which first methodological integration took place(Vlek et al., 2003). These three foci comprise 1) the exchange between land surface and atmosphere, 2) land-use change, and 3) water-use optimization. These three foci are characterized mainly by the easiness of communication between the scientists in the connected sub-projects. The project recognized that the applied models and methodologies in each subproject are close enough as not to cause fundamental communication problems. The project first strategically integrated the scientists of the subprojects; full integration will be achieved in the final stage of the project.

Within each foci, methodological integration has been carried out by adopting multi-agent system approaches. Two different multi-agent systems are currently under development: one for land-use change modeling and the other for water-use optimization. This paper only describes a prototype of a spatially explicit, dynamic land-use change simulation model: GV-LUDAS(GLOWA-Volta Land Use DAynamic Simulator). A detailed description of the water optimization model is available in Vlek et al.(2003).

GV-LUDAS is designed to simulate complex and dynamic interactions between natural resources and human actors by coupling cellular automata and agent-based models. The computational framework is based on an objective-oriented language, NetLogo, which has been developed

〈Figure 6〉 Overall methodological framework for integrated modeling approach of the GLOWA-Volta land-use cluster



language, NetLogo, which has been developed by the complexity theory research group of the Northwestern University, USA. 〈Figure 6〉 shows the overall model components implemented in the model structure. In this framework, the heterogeneity and continuous changes in natural environment conditions are presented as layers of a two-dimensional grid. Each grid stores the status of each environmental parameter; these parameters will be continuously updated every time step. The main natural processes considered are hydrological water balance, erosion-deposition over the surface, vegetation growth functions in naturally vegetated areas, and crop growth functions in agricultural lands. A tight coupling with existing deterministic models is not intended due to the limitation of computation and complexity of the model structure. Instead, key processes will be reinterpreted as more abstract functional equations and implemented within the model.

The inclusion of human decision-making processes for different land-use options will be the major challenge when building this model. During the first phase, it was recognized that the study area is characterized by an extreme diversity of land-use change processes. The Multiscale Adaptive Model(MAM) shows that correlation between actual land-use changes and various environmental factors is strongest at the finest spatial resolution, and then decreases gradually with increasing spatial coverage(Park et al., 2003).

resolution(e.g., household level) is the best to characterize the land-use change processes. In actual land-use change processes in the predominantly agricultural society, individual households make the land-use decisions, and we can easily anticipate that they may apply totally different land-use strategies based on their individual economic household situation, technological adoption, and their customary social regulation. It should be noted, however, that the greatest constraint for process-based land-use change modeling is not the lack of methodologies, but the lack of appropriate data in such a fine spatial resolution. This is the especially the case for the socio-economic variables. Therefore, a compromise is necessary to include sufficient details of land-use drivers and also the heterogeneity of decision-making processes.

For the proposed model, the villages will be considered as individual decision-makers or the optimum spatial unit to model socio-economic behaviors. It is a well-known fact that human behavior varies with group size; for example, groups of people will make more risky decisions than individuals. Decision-making at the village level is often strongly influenced by local and national institutions. Therefore, considering the village as an actor might include the influence of institutional impact in land-use-related decision-making processes. Since the spatial extent of this modeling cover a large area(400,000km^{2}), village-level modeling might be more effective for upscaling and downscaling of developed land-use change models to other spatial scales. The village level spatial information is often available from national census data and other socio-economic surveys(e.g., Ghana Living Standard Survey(GLSS) in Ghana). In the GV-LUDAS, an individual agent(village) stores its own variables that represent the characteristics of agent behavior and actual socio-economic status. These variables will include possible land-use-related socio-economic variables, such as population, demographic structure, consumption, market orientation, land tenure, the existence of resource management institutes, etc.

The next challenge is to model the interactions between spatially distributed natural environments and socio-economic drivers. Various modeling strategies are already documented(see Irwin and Geoghegan, 2001, Aggarwal et al.., 2002). Considering the data requirement for socio-economic modeling and also the spatial scale of individual actors(village), a rule-based system is currently implemented, but the possibility to implement mathematical programming is also pursued. The specific rules for individual villages will be directly derived from empirical relationships and actual census data of the years 1984 and 2000. The results from the socio-economic survey under the framework of the 'common sampling frame' may provide further information(see the section above).

3) Problems of communication[1)]

Communication among scientists and also with stakeholders has not been easy in the GLOWA-Volta project, but the project has made interesting conceptual progress. The process was supported by special circumstances. At the practical level, the Center for Development Research(ZEF, Bonn) is an interdisciplinary institute where ecologists, economists, and anthropologists work under one roof. The foundation of ZEF was specifically designed to accommodate the recent paradigm shift within development communities: capacity building and sustainable development(ZEF, 2002). The simple physical proximity of the scientists involved proved to be extremely useful for the exchange of ideas and implementing integration through a trial-and-error approach. Probably more important is the fact that an interdisciplinary center tends to attract people oriented to working with scientists in other disciplines. In this case, the team consisted mainly of recently graduated post-doctoral scientists, who brought along the necessary mental flexibility to try new approaches and were willing to take the associated risks.

At the conceptual level, two factors were important. First, the scientists involved shared a common goal that was clear and tangible, resulting in a common sampling frame and water-use optimization model. This situation differs from many multidisciplinary projects in which the individual scientists study the same object. Typically, in such cases, the scientists first scatter to measure and model disciplinary aspects. At the end of the project, these different threads then have to be, somehow, tied together. In the GLOWA-Volta project, the shared goals focused the different efforts and forced integrated thinking from the onset.

The second useful conceptual factor was the insistence on quantification and modeling, rather than on engaging in discussions that highlight differences in underlying philosophies. The reality of actual processes on the ground is extremely complex, and the main research agenda is clearly a combination of academic and political agenda. A certain willingness to simplify and understate the importance of disciplinary findings often seems an essential first step in integrative research. Building a (quantitative) model as a team can be helpful in putting one's own input in proper perspective.

From the above, it becomes clear that integrative science comes with a relatively large overhead in coordinating. One has to agree on goals and approaches, understand the basic principles of other disciplines, and explain one's own discipline to non-experts. The development of the Common Sampling Frame brought these requirements to the fore. The soil scientist, for example, had to develop special GIS tools to aid

1) This section is a summary that has been published in Vlek et al. (2003)

the sampling stratification and develop specific research protocols for the physical observations made during the survey. Undoubtedly, it would have meant less effort if the soil scientist himself had collected the information on the soils in the Volta Basin that he had received in return. However, it was essential to directly couple the social and physical information in order to model land- and water-use dynamics.

V. GEOGRAPHERS' COMPARITIVE ADVANTAGE IN INRM

The success of any INRM requires inputs from not only different academic disciplines, but also actors involved in policy development, such as local stakeholders, NGOs, policy-makers, etc. While the importance of individual participants should not be underestimated, geographers have clear comparative advantages in solving the technical problems of an INRM research described before.

The problems of scale is closely linked with the methods to capture the complexity of human-related and natural phenomena over the landscape. The complexity of geographical features often forces scientists and policy makers to investigate the 'average' condition of systems, frequently ignoring variance characteristics. As an example, the spatial variation of environmental processes has long been considered as a complicating factor for traditional farming research. The only way to take account of such variability is to increase the number of trials(repetition) to remove 'noise' and 'error' associated with spatial variation. This might also be true for traditional economic analyses. Mainstream economic models prefer building a model as a tool for policy decision support. On the other hand, geographers have a rather opposite perspective on spatial variability. Space has been seen as integrating interactions amongst phenomena. Therefore, the explicit study of spatial variation can be seen as a means of better understanding of these interrelationships(Carter, 1997).

Previously working on the spatial variability is often considered as 'descriptive' science, not because of its conceptual irrelevance, but due to the lack of methodology to capture such complexity. During the last few decades, geographers have observed the development of quantitative tools for handling the spatial and temporal diversity of human-nature interactions. With new advances in spatial information technology, including geographic information systems(GIS) and remote sensing, spatial diversity can be now quantitatively approached. GIS has been particularly useful for visualizing spatial patterns of various geographical phenomena and for representing interactions among spatial units. Recently, new possibilities have been created, as GIS is becoming tightly coupled with remote

sensing, spatial statistics, and spatial simulation models. Supplementing application-oriented aspects(e.g., spatial analysis to identify policy options), spatial information systems can be characterized as regional study tools involving the integration of spatially referenced data in a problem-solving and planning environment at different spatial and temporal scales(Burrough and McDonnell, 1998).

The integration and communication of knowledge are another deep-rooted traditions of geography. Geography aims to study natural and man-made phenomena relative to a spatial dimension. It is not surprising to see the diverse nature of geographers' research topics under such a definition. The foci of the integration in geography is 'region', which is often defined spatial unit where physical and human-related features are relatively homogeneous. The geographer's tradition is to divide the world into smaller areas for the convenience of study, but such divided regions are functionally connected in a hierarchy of areas. While individual research topic of geography have clear overlaps with other academic disciplines, they are combined together to understand the relationship between humans and nature over the region.

Unfortunately, the tradition of integration within geography had largely been underestimated even by geographers themselves during the period of generalization, quantification, and specialization (O'Brien, 1991). However, it is the right time to think anew this integration. As discussed before, the quantitative and specialized discipline often failed to solve real world problems. The integration of knowledge is a new demand for any INRMS, and close collaborations with other disciplines is extremely important to solve a regional problem. As we observed in the GLOWA-Volta project, simple physical affinity is an enormous help when solving a problem from different perspectives. Since geographers often share the same educational backgrounds focused on regional concept and space, integration of knowledge should be much easier than in other fields of science.

Above all, geographers are often named as people who describe the interactions between people and place, and identify the difference among places. The description of foreign nations and newly discovered lands were the main job of geographers during its early academic development(Pattison, 1964). The tradition of such 'regional studies' was severely undermined during the last century, due to the descriptive-empirical nature of regional studies and ever increasing globalization(O'Brien, 1991). Considering the new development paradigms described in section 2 of this paper, it is now clear that this criticism is an ill-found and short-sighted. Globalization is a clear trend in the modern society, but it is also true that development at localities are only possible when the natural and human-related conditions were met to the global trends in economic and cultural processes(Massey and Jess, 1995). In order to understand the

development and reduce the poverty in a developing countries, systematic understanding on the cultural and social diversity at local level should have the first priority.

In summary, the advance of relatively new paradigms in sustainable development issues indicates that geography as an academic discipline has clear conceptual and methodological advantages in recent natural resource management studies and development issues. The author has often been exposed to strong resentment expressed by media and governmental sectors, arguing there are not enough Koreans working in international communities despite its economic status. Our society certainly demands more active role from geographers in this regard. Increased knowledge and understanding about different regions is essential for Korea if the country is to be a respected member of the international community. At the same time, studies in other countries will bring in cultural and ideological diversity to homogeneous Korean society.

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