# SUMMARY FINAL REPORT OF THE PILOT STUDY ON THE USE OF LANDSCAPE SCIENCES FOR ENVIRONMENTAL ASSESSMENT

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## A. INTRODUCTION

1. The assessment of land use and land cover is an extremely important activity for contemporary land management. Human land-use practices (including type, magnitude, and distribution) are the most important factors influencing environmental management at local, regional, national, and global scales. In the past, environmental policies have often reflected a reactive response to environmental perturbations with management efforts focused on short-term, local-scale problems such as pollutant abatement. Currently, environmental management philosophy is evolving toward examination of critical environmental problems over larger spatial scales and assessment of the cumulative risk resulting from multiple problem sources. Today's environmental managers, urban planners, and decision-makers are increasingly expected to examine environmental and economic problems in a larger geographic context that crosses national boundaries and scientific disciplines. Secondly, contemporary policy-makers have also been challenged on how they view security. The conventional definition of national security has been expanded to include environmental threats resulting from resource scarcity and overpopulation and it is recognized that environmental factors may have an impact in creating conflict and world instability. Thus the working definition of security has been broadened beyond relying on militaristic aspects alone and has evolved to include the environment.

2. To meet the challenges associated with evaluating environmental problems related to land use at multiple spatial scales, understanding the consequences of environmental change, and to examine non-traditional threats to security, a Pilot Study on the Use of Landscape Sciences for Environmental Assessment was launched in March 2001 in the framework of the former NATO Committee on the Challenges of Modern Society (CCMS).

3. Specifically, the Pilot Study was developed to explore the potential of quantifying and assessing environmental condition, processes of land degradation, and subsequent impacts on natural and human resources (including security) by combining the advanced technologies of remote sensing, geographic information systems, spatial statistics, and process models with landscape ecology theory. The Landscape Sciences Pilot Study was co-chaired by the United States and Germany and designed to enhance the ability of senior-level decision-makers, environmental managers, and the public to 1) address a range of environmental problems that have inherently different scales; 2) evaluate cumulative impacts to ecological and hydrological resources; 3) provide a framework for large-scale assessment in which to put surrounding communities in perspective; 4) communicate analysis and assessment results to a wide range of technical and non-technical audiences; and 5) develop products, such as regional and watershed assessments, analysis tools, digital maps, and databases for a variety of international audiences.

4. The Pilot Study enlisted a working group of representative NATO Member and Partner nations to exchange information and technology about landscape science approaches useful for environmental assessment. The landscape sciences project uses landscape ecology, i.e., the study of the distribution patterns of communities and ecosystems, the ecological processes that effect those patterns, and changes in both pattern and process over time, as its foundation. The research focused on the interaction between landscape patterns and ecological processes and their relation to environmental security. Environmental assessment is defined as a process by which scientific evidence and technological information are analyzed for the purpose of evaluating present condition or forecasting the outcomes of alternative future courses of action. The assessments were directed toward specific ecological resources and socially relevant endpoints such as watershed condition (water quality, quantity, and vulnerability to flooding), landscape resilience (ability to sustain ecological goods and services when subjected to conditions of anthropogenic and natural stress), and biodiversity (wildlife habitat). The research and implementation agenda of the Pilot Study was accomplished through the completion of multiple national studies throughout Europe and the United States which emphasized thematic areas related to landscape characterization, land cover change detection, landscape indicators, landscape assessment, and landscape theory and models.

5. The contributions of the participating countries (see title E) have been summarized and submitted to Springer for publication under the NATO Security through Science Book Series C (Environmental Security) with the purpose that providing new approaches and methods based on the landscape sciences will be helpful in assessing various aspects of environmental security. It is anticipated that results from this Pilot Study will illustrate the utility of adopting a landscape sciences approach in public health and environmental decision-making, natural resource management and planning, and ecological preservation/restoration projects. The landscape assessment framework and methodologies should provide a number of key benefits to environmental managers and the public in regard to determining how different land-use choices impact ecological integrity and subsequently, environmental security.

6. The relationship between environmental change, stress, and environmental degradation relative to the issue of security has garnered increased importance as new challenges have emerged since the end of the Cold War. The question of the relationship between environment and security is now a common interest among both the scientific and policy communities especially as the traditional security concepts based on national sovereignty have been revisited following changes in the European political landscape at the end of the last century. The definition of security now at least incorporates non-traditional threats and their causes, Environmental stress and social, economic, and environmental factors are now being factored into an evolving definition.

7. The predominant considerations in many parts of the world for environmental management decisions and ecosystem protection include understanding and establishing land- and resource-use priorities, establishing time frames for management, using comparative evaluation and assessment analyses, and clarifying where decision authority resides (i.e., local, regional, national, international). It is a challenge for both scientists and decision-makers to include all these considerations and communicate effectively among multiple user groups. As a direct result of increasing discussion and research about the potential for large, regional-scale environmental changes and the general acknowledgment of the relationship between environmental change and human social, economic, and demographic issues, there is now more attention paid to the question of the relationship between environment and security. Thus this Pilot Study on the use of landscape sciences provides a multi-lateral forum for cooperation, information exchange, and dialogue among the environmental, development, foreign and security policy communities. Additionally, it provides an “enabling environment” to facilitate joint work

programs and further advances the NATO goal of utilizing a science framework to promote international cooperation and peace.

## B. SUMMARY OF CONTRIBUTIONS AND FINDINGS

8. A number of conceptual approaches and case studies that dealt with various aspects of environmental security were applied throughout the Pilot Study. Many of the contributions dealt with specific *types of drivers and pressures*, and specific environmental themes and landscape services. Additionally, the Pilot Study addressed conceptual approaches and case studies for a broad range of general environmental themes or values that relate to landscape provisional and organizational/regulatory services. These included terrestrial and aquatic biodiversity and habitat quality, conservation of protected areas, water quality and quantity, terrestrial ecosystem productivity, and human cultural landscape diversity.

9. Comprehensive *conceptual models* were presented that link a number of potential drivers to environmental security, including political, social, and economic drivers that can influence wholesale changes in the pattern and extent of land use, each of which can affect a range of services. These conceptual models provide a good summary of our understanding of the causes of landscape change and potential impact on environmental security at different scales. They also provide a basic framework for the types of data and indicators needed to address aspects of environmental security.

10. A number of national contributions to the Pilot Study analyzed and discussed current and projected changes in human *demographic patterns* and how they might drive changes in landscape services and environmental security across Europe. These included projections of declining populations and population shifts to urban environments. Both of these likely reflect economic realities; because of financial limitations or changes in social values, people are waiting longer to have children, and better employment opportunities exist within urban areas. Population decline in rural areas reduces the tax base and results in critical infrastructure losses, further accelerating the spatial redistribution of people to urban areas. However, results also suggest that the pattern of population shift may vary considerably across Europe. For example, some urban areas in Germany may experience fragmentation processes. Larger urban populations and increased spatial extent of urban areas (e.g., urban sprawl) result in a number of landscape changes that potentially will have impacts upon important landscape services. For example, urban expansion can result in loss of forests that provide services such as timber and paper products, removal of air pollutants, hydrological regulation, sequestration of carbon and production of oxygen, filtration of nutrients and sediments from streams and rivers, and habitat for animals and plants. Similarly, urban expansion can result in loss of productive agricultural lands which reduces food production, increases in impervious surfaces that increase the frequency and magnitude of flooding, and increases in pollution load and exposure to people living within and around urban areas. Additionally, loss of people from rural areas can result in accelerated loss of soil, increases in nutrient loads, and increased flooding because people often maintain practices and structures that maintain services. The changes in human demographic patterns described in the Pilot Study provide valuable insight into future landscape changes and potential changes in environmental security.

11. A number of contributed projects dealt with specific *types of pressures or threats*. These included urbanization, agricultural expansion onto lands that are marginal for growing crops or grazing, climate change, and nuclear safety. Each of these projects provided conceptual frameworks or results from case studies linking specific pressures and threats to changes in landscape states. Many of the contributions dealing with pressures or stressors also addressed fundamental changes in landscape condition.

12. Other contributions addressed methods to assess *landscape state* and changes in state. This involved application of metrics, indicators, and models related to landscape structure, and in some cases, function. They also included development and application of sampling strategies that linked in-situ measures to spatial data, as well as remote sensing techniques to detect and evaluate change. Two contributed projects provided indicators for changes in scaling functions that relate to fundamental changes in ecosystem and landscape processes. In the former, an approach was developed to characterize and interpret the spatial patterns of change as disturbance at multiple scales in a panarchy of nested, bounded, and organized social-ecological landscapes (SELs) like region, province, and county, taking into account the scales and spatial patterns of human land use as source/sink disturbance systems. In the second project a new theoretical approach was introduced that links the allometry of energy partitioning among different-sized organisms in ecological community-to-community stability. The new approach makes it possible to quantitatively estimate not only the scaling exponents in the dependence of population density and biomass of heterotrophs on body size, but also the absolute values of energy fluxes claimed by organisms of a given size in stable communities, which then can be used as an indicator of an ecosystem state.

13. A primary conclusion of the Pilot Study was that there is a paucity of in-situ data across and within regions of Europe, and that this deficiency prevented a more thorough interpretation of the consequences of landscape change on provisional and regulating services. Additionally, differences in spatial resolution and extent of existing biophysical coverage across many areas of Europe prevent broad-scale application of spatially distributed landscape models and indicators that would link landscape state and change to provisional and regulatory services.

14. Nearly all of the case studies that addressed landscape state and change identified potential relationships between state and change, and provisional or regulatory *services.* For example, changes in natural vegetation along streams (riparian vegetation) can be linked to increases or decreases in nutrient and sediment filtering services. In some cases these linkages were quantified from existing empirical studies or models. For example, watershed models were used to determine the degree to which landscape state and change influenced provisional services, such as clean water, and regulatory services such as nutrient uptake, sediment filtering capacity, and flooding abatement. In one case study, a landscape provisioning service (phosphorus uptake) was directly measured and linked to a variable of landscape state (vegetation biomass per unit area and percent vegetation cover).

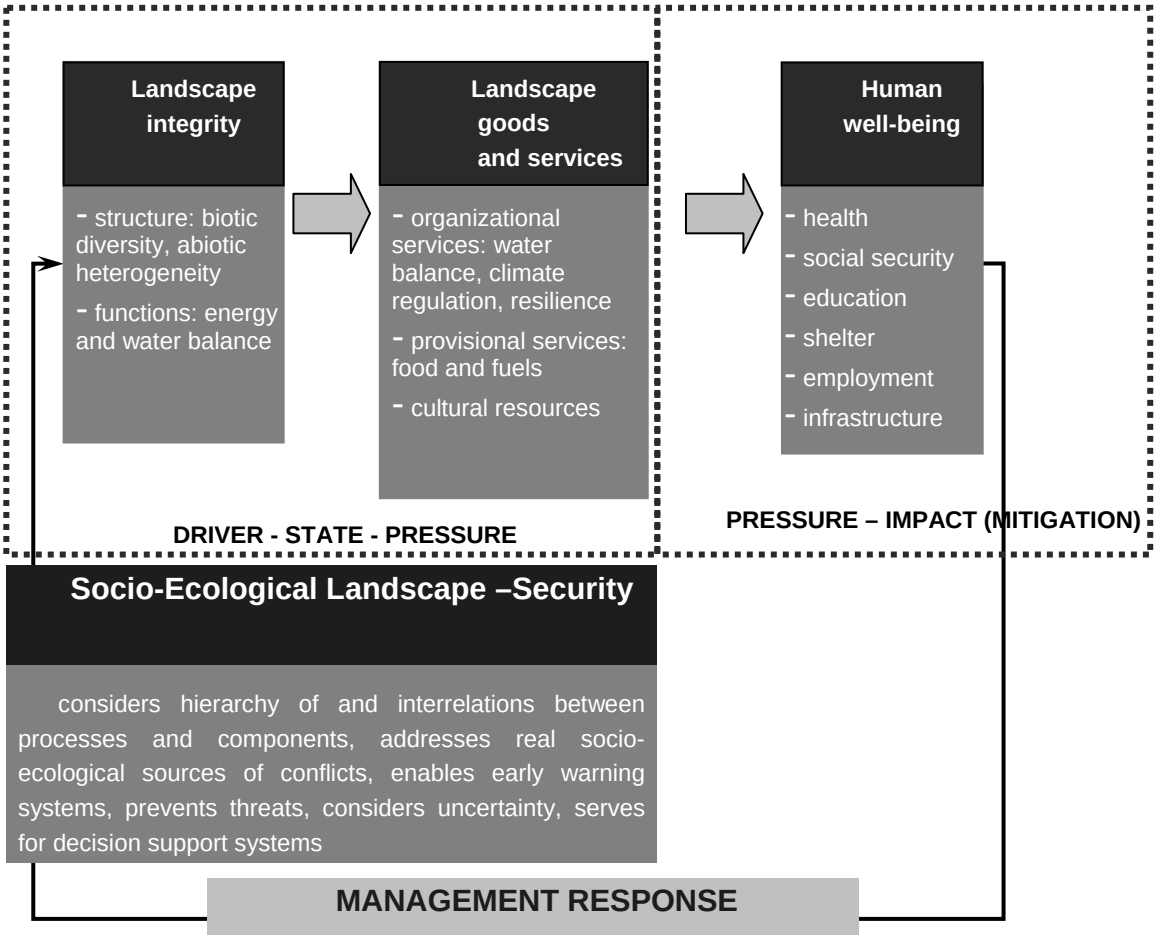
15. Four types of approaches were presented in the Pilot Study that relate to management or *policy responses* that offer potential to improve or protect environmental security. These include 1) alternative futures analysis, 2) multi-indicator scenario analysis, 3) monitoring designs and systems to assess the effectiveness of policy and management, and 4) adaptive management strategies. Alternative future (scenario) analysis uses spatially distributed watershed or landscape models to link potential landscape management alternatives to provisional and regulatory services. The important feature of this approach is that the spatially distributed models have land cover or land surface parameters such that changes in these parameters that can be related to changes in services. Moreover, because of these linkages, it is possible to develop spatially explicit management alternatives (e.g., responses) to improve or protect environmental security. The multi-indicator scenario approach utilizes amoeba diagrams to evaluate alternative management options. This approach also requires that indicators can be related to specific provisional and regulatory services. A strength of this approach is that multiple indicators and services, and their potential responses to different scenarios, can be displayed in a small set of diagrams. This increases the ability of the decision-maker to interpret complex indicator datasets. A combination of these two approaches would be a valuable next step. A critical component of evaluating the effectiveness of management scenarios and policy changes (e.g., that affect drivers) is

development and application of multi-scaled *monitoring strategies*. Finally, *adaptive management* involves evaluation and re-evaluation of management and policy prescriptions and makes management and policy adjustments based on a set of performance indicators.

## C. THE LANDSCAPE SCIENCES APPROACH, ENVIRONMENTAL SECURITY, AND MANAGEMENT RESPONSE

16. Studies developed and presented as part of this Pilot Study demonstrated that inclusion of landscape sciences into a framework of environmental security is highly recommended. A landscape perspective considering the spatial arrangement of land-use types at multiple scales is essential to a more appropriate indication of environmental security. Heretofore, decision-makers and the public have focused on changes in delivery of ecological services and mitigation of resulting conflicts, rather than on the drivers and sources of disturbances that occur at multiple scales, which jeopardize organizational, cultural, and provisional services. Additionally, important biological components and processes of ecosystems have been largely missing from the objective assessments of environmental security. The majority of proposed solutions have been based on chemical and physical analyses, and remediation and engineering methods and technologies have been implemented on a case-by-case basis at a local scale (bottom-up approach). Yet, many of the drivers and pressures exert their influence from multiple scales. In contrast, a landscape approach to environmental security concentrates on the identification of hierarchy of, and linkages between processes and components across scales and multiple environmental themes and issues (Figure 1).

**Figure 1.** The landscape sciences approach, environmental security, and management response.



17. The landscape approach is prospective and prescriptive rather than the more traditional, reactionary, and retrospective approach (impairment focus, Figure 1), and as such, offers the potential to identify critical drivers and pressures and to avoid future declines in environmental security. It also offers the potential to establish and protect critical landscape provisional, regulatory, and cultural services. Through the concept of ecological hierarchy and adoption of the panarchy theory, the landscape sciences also provide a framework for addressing multiple-scale interactions between pressures (e.g., anthropogenic drivers, climate change), sensitivity, condition, and potential trajectories of social-ecological landscapes. Because the landscape sciences produce spatially explicit relationships, it provides a way to evaluate how alternative landscape futures and management scenarios (e.g., response) might increase environmental security. It also provides a novel framework upon which to implement adaptive management strategy.

18. Adaptive management is focused on retrieving and improving aspects like social learning and traditional knowledge through learning-by-doing. In this context, the landscape sciences provide insights into spatial relationships between factors influencing environmental conditions (e.g., drivers and pressures), the inherent capacity or resiliency of a given area based on its biophysical attributes (e.g., an areas' sensitivity to different drivers and pressures), and the area's environmental condition (state) and trends (impact and trajectory). When combined with information on social and cultural values and expectations, the landscape sciences approach provides a way to evaluate an area's relative environmental *securability*, e.g., the likelihood of being able to change or to maintain a landscape state whereby important landscape services are obtained or preserved over long periods of time.

19. Such an approach and concept could be an important addition to the concept and the practice of adaptive management. That is, a primary follow-on to adaptive management from the landscape approach which is prospective and prescriptive. Furthermore, possible discordances between objective and subjective analyses can represent an important added determinant of *securability*, in that the likelihood to bridge that gap will contribute to the likelihood of being able to change or maintain a landscape state in the future whereby important landscape services are obtained or preserved.

20. Areas with low levels of securability would require greater levels of attention and human and capital investments whereas areas with relatively high securability would require less intervention but would still require monitoring.

## D. RECOMMENDATIONS

21. The Landscape Sciences Pilot Study provided a number of important insights and case studies on how the landscape sciences can be used to address environmental security. However, an opportunity exists to expand the application of the findings in this project to a more comprehensive and integrated approach that potentially could address multi-environmental themes and threats at a range of spatial scales. In order to exploit this potential, future studies should be focused on development of reliable, integrated risk assessment methods and quantitative measures from a landscape perspective to evaluate both vulnerability and uncertainty associated with environmental security at different scales and hierarchical levels. One immediate goal could be to develop a decision support system, tool, and/or concept that would allow users to reduce and avoid conflicts among environmental security decisions with consideration of peoples' perception of threats. This would involve landscape scenario analysis, including an in-depth investigation of linkages between drivers, pressures, states, impacts, and responses, with special focus on incorporation of demographic, economic, and social factors including the perception of threats. It will also be important to understand the role of humans in maintaining ecosystem services, especially in that humans maintain cultural-ecological landscapes that provide important services (e.g., prevention of soil erosion, landscape mosaics that support biological diversity, etc.). To apply such a

political conception, a number of questions have to be examined, which could also lead to future research activities. The respective fields of problems might be investigated in a potential future project, which could take into account the following steps:

1. Select 3 to 5 regions in Europe and North America that represent biophysical, cultural, and demographic gradients. These gradients would be used to evaluate metrics and indicators representing the full range of drivers, pressures, and states. Develop these for multiple provisional, regulatory, and cultural landscape services;

2. Develop methodologies to characterize securability. This would include biophysical, cultural, socio-political, and economic classifications with regards to relative environmental securability;

3. Apply securability classifications in each study area at multiple scales and hierarchical levels in a panarchy of nested, bounded, and organized socio-ecological landscapes (SELs) like region, province, and county;

4. Develop an alternative landscape futures decision support tool that permits an analysis of alternative management scenarios given different levels of environmental securability;

5. Apply the amoeba diagram approach to assess changes in multi-indicator values given different alternative future scenarios;

6. Apply the decision support tool in each of the study areas and hold public workshops to get feedback on results;

7. Modify the approach and decision support tool based on public workshops and implement the approach as part of a comprehensive management strategy among NATO members and partners.

22. Finally, with regard to the set of questions, tasks, and challenges presented in this report, we offer the following conclusions:

- Landscape sciences comprise a very high potential to address and assess environmental security. Due to the typical scales of observation, landscape ecological methodologies are most suitable to link social, physical, and biological sciences, which is an important formal precondition for a successful assessment of environmental security.

- Landscape security is a very young concept which has to be integrated into the canon of environmental developmental targets, such as ecosystem/landscape integrity, health, and sustainability. Environmental security illuminates specific societal demands which can not be enlighten by the corresponding concepts and approaches.

- The contributed projects in this Pilot Study have shown that there are several significant landscape components related to environmental security. Basing on the knowledge of their organization, it is possible to reduce the number of significant variables to create a manageable set of security indicators.

- On the basis of these indicators and a linkage with well-known landscape methodologies, an evaluation of the state of environmental security becomes possible at the landscape level, i.e. if linked with scenarios of different possible futures.

23. From the contributed projects, it has furthermore been demonstrated that landscape sciences can offer several tools, such as indicators, models, monitoring strategies, and assessment approaches which can be combined to capture security items and to better understand the complex interrelations of human-environmental systems. These instruments can be used to perform long-term analyses of landscape potentials as well as the respective risks and threats. Therefore, they are good prerequisites for an integrative, interdisciplinary strategy for environmental security.

24. In spite of these large methodological potentials many problems still have to be solved. But application can be presently carried out if the linkages between the environmental components and their respective scientific and policy communities are improved and integrated into a common understanding of security. Thus, the development can be accelerated if there is a focus and commitment for a joint endeavour with the focal target of integration, on a scientific, environmental, and political level.

**ACKNOWLEDGEMENTS**

25. Based on the success of the project, the participants want to make a concluding recommendation. We have been cooperating for a number of years within the Pilot Study format on landscape assessments. The scientific targets of the project have been fulfilled in a satisfactory degree and the productivity of the group has been overwhelming. There has been a deep exchange of methods and knowledge and several problems of the national working groups were solved due to the assistance of the Pilot Study colleagues. Furthermore, new ideas were realized due to a joint methodological or conceptual development. Therefore, the Pilot Study format has been a very successful instrument for all of us, and we therefore strongly urge the continued incentive to bring scientists from many countries together, which otherwise may not have contact without the pilot study support mechanisms. Therefore, we are grateful to the colleagues, managers and supervisors from NATO for giving us this unique chance. We want to thank all the colleagues who participated for their contributions and for the wonderful opportunity to make new friends. Lastly, we want to especially thank Ms. Martine Deweer and Ms. Susan Williamson (NATO Public Diplomacy Division) and Ms. Lynn Schoolfield (USEPA, Office of International Affairs) for all their support, guidance, and valued advice.

## E. PILOT AND PARTICIPATING COUNTRIES

*Pilot Countries and Co-directors:*

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*NATO Members:* Bulgaria, Germany (Pilot Study Co-Director), Italy, Latvia, Lithuania, Norway, Poland, Romania, Turkey, United Kingdom, United States (Pilot Study Co-Director)

*NATO Partners:* Austria, Finland, Georgia, Russian Federation, Ukraine

*NATO Contact Country:* Australia

## F. MEETING DATES

a) Las Vegas, Nevada, USA (Inaugural Meeting); 3-5 April 2002
b) Salzau, Germany; 19-21 November 2002
c) Debe, Poland; 1-3 September 2003
d) Lecce, Italy; 5-9 September 2004

e) Veliko Turnovo, Bulgaria; 4-8 September 2005
f) St. Petersburg, Russia; 3-6 July 2006

**PROJECT PROCEEDINGS AND OTHER PRODUCTS.**

**I. Web site**

NATO/Science for Peace and Security web site for Landscape Sciences Pilot Study (http://www.nato.int/science/pilot-studies/lsea/lsea-index.htm)

**II. Published Proceedings**

a) Kepner, W., Kutz, F., Müller, F., and Sajwaj.T. 2002. Final Report. NATO/CCMS Pilot Study Organizational Meeting; Use of Landscape Sciences for Environmental Assessment. 54 pp.

b) Müller, F., Kepner, W., and Caesar, K. (eds.). 2003. Landscape Sciences for Environmental Assessment. Proceedings from a CCMS Pilot Study Meeting at Salzau Castle, Germany.
EcoSys Vol. 10, 174 pp.

c) Müller, F., 2004 (ed.). Landscape Sciences for Environmental Assessment. Proceedings from a CCMS Pilot Study Meeting at Debe, Poland.
EcoSys Vol. 42, 115 pp.

d) Petrosillo, I., Zurlini, G., Kepner, W., and Müller, F. (eds.). 2005. Landscape Sciences for Environmental Assessment. Proceedings from a CCMS Pilot Study Meeting at Lecce, Italy.
EcoSys Vol. 11, 168 pp.

**III. Security through Science Book Series: C**

*Use of Landscape Sciences for the Assessment of Environmental Security* (2007). Springer, The Netherlands. Published in cooperation with NATO Public Diplomacy Division.

**IV. Analytical Tools**

Automated Geospatial Watershed Assessment (AGWA) tool (http://www.epa.gov/nerlesd1/land-sci/agwa/introduction.htm).

AGWA is a GIS-based hydrologic modelling tool that provides an analysis system for environmental managers, natural resource specialists, policy-makers, scientists, and the general public to perform watershed assessments at multiple spatial and temporal scales.