# Sustainability: Beyond Antrhopocene

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## Abstract

Advances in science and technology have heralded an era of unprecedented global prosperity and wealth for a large segment of humanity. At the same time significant pockets of many problems such as poverty, inequality, remain unsolved. We are also beginning to experience the impacts of over exploitation of natural resources and other anthropogenic impacts on earth systems functioning at planetary scale. Traditional compartmentalized approaches to knowledge generation by different disciplines that worked so well in the past, cannot address the complex interwoven global problems of today. It is necessary to find ways to address problems in an inter-disciplinary manner that promotes a holistic viewpoint. While the traditional discipline based knowledge generation has been very effective in advancing knowledge and technology, we need new platforms where one can address interlinked problems in an efficient and effective manner. It is also important that the solutions we seek are targeted towards development that is equitable and sustainable. Hence it is important to link the solutions we seek with global development agenda and concrete actions required to achieve them. This paper describes the approaches to sustainability, sustainable development, global development agenda and how they may link with postgraduate education with experiences from the postgraduate program of UNU-ISP.

## Environment and the Earth System Sustainability

The recent adverse impacts of global environmental change such as climate change, biodiversity loss, global water scarcity has renewed global interest on the need to address human development and global sustainability linkages in a systematic manner. Global environmental concerns in global agenda grew since late 1960's with the realization of the difficulties associated in trying to meet needs of rapidly growing population with ever increasing demands from earth's limited resources. The space travel also contributed to the understanding of limited earth resources when earth is viewed from space as a 'living spaceship' with interconnected environmental processes and finite resources. The UN Earth Summit in Stockholm in 1972 was instrumental in channeling these concerns towards a global movement that demanded regulation and control of impacts of human development activities on nature. The UN report on development issued by World Commission on Environment and Development, Our Common Future (1987) also known as "Brundtland Report," provided a common platform for different stakeholders and interest groups to discuss ways to address this common goal within each discipline. Its definition of sustainable development as the "development, which meets the needs of the present without compromising the ability of future generations to meet their own needs" has linked the resources and services of earth environment across generations. The report was followed by the United Nations Conference on Environment and Development (UNCED) in 1992 in Rio de Janeiro that produced a detailed action agenda, the agenda 21, and was instrumental in setting up UN conventions on Climate Change and Bio Diversity. In 2002 the World Summit on Sustainable Development held in Johannesburg, South Africa reiterated the commitment to address the relationship between the human society and natural environment. The summit came up with an agenda of five priorities, water and sanitation, biodiversity and ecosystems management, energy, agricultural productivity, and health for promoting both development and sustainability (Annan K., 2002). These conferences and activities in-between them has greatly facilitated in generating global interest and follow up on the human development activities and their linkages and dependence to earth environment.

**Addressing Sustainability**

While the definition of sustainable development does not provide a precise mechanism for quantifying sustainability, the flexibility it provided allowed different disciplines to explore its meaning and to communicate across disciplines (Daly, 1990). The discussions within each discipline have been converging towards inter-disciplinary approaches on the basis of 'sustainable development' objectives. For example, as a discipline, economics is usually concerned with allocation of limited resources across all needs in an efficient manner. The primary focus of economics as a discipline on sustainability is the trade off of current consumption for future consumption (Elliot, S. R, 2005). However, the traditional measure of success of economy as the growth of GDP in a given time does not address the issue of resource depletion or use of non-renewables in generating this wealth. The capital used to produce goods needs to be viewed from a sustainability viewpoint to clarify the relation between nature and human needs. The total stock of capital may be considered as the sum of natural capital (Kn), i.e, the resources that come from nature, the human capital (Kh), i.e. the knowledge and technology people bring to the production and the capital created (Kc) such as infrastructure and machines. According to Elliot (2005) a group of economists argue for a weaker form of sustainability, where, as long as the total capital remains unchanged the current generation can use a larger share of Kn and leave future generation with increased Kc (better and efficient machines and technology) and Kh (improved knowledge). On the other hand there is an opposing group of economists who do not consider that these different forms of capitals as substitutes. This second group belongs to the discipline 'Ecological Economics' that has been established more than 20 years ago to discuss the relationship between economics and ecosystems. They subscribe to a 'strong sustainability' view that requires maintaining both man made and natural capital intact separately (Dally, 1990). This approach requires addressing the issue of non-renewables essential to maintain human economic and development activities today. Dally (1990) suggested a way of overcoming this difficulty by proposing to invest in renewable substitutes for non-renewables, so that when the non renewable resources are depleted there will be renewable substitutes to take their place. In a recent article in BioScience, Raudsepp-Hearns and colleagues (2010) challenged this notion that ecological damage will eventually lead to decline in human well being by pointing out, in spite of the declining ecosystems services as identified by Millennium Ecosystems Assessment (MA, 2005), the human well-being has been steadily

increasing as captured by the continuous increase in human development index (HDI).
However, the sustainability approach should not be viewed from a reductive stock-flow framework where natural capital is only producing eco-system services, but holistically considering the complexity, irreversibility, uncertainty and ethical predicaments intrinsic to the natural environment and its connections to humanity (Ang and Passel, 2012).

According to Baumgärtner and Quaas (2010), ethical considerations of sustainability economics need to go beyond the economics-environment relation and aim at justice (a) between human generations (b) within a human generation and (c) between nature and humans. The objectives of economics and social sciences go beyond the domain of justice between humans and nature. It targets the aspiration of every human to address the needs and wants in an equitable manner. Based on the above they argue that sustainability economics should be based on efficiency of resource allocation to achieve two normative goals of (i) achieving needs and wants of individual humans and (ii) promoting justice as given from (a) to (c) above. The aspect of justice towards nature in (c) is important not only as a justice towards intrinsic value of nature and consideration for other species who share the earth with humans, but also because of the importance of preserving the interconnectedness among earth system processes needed for the regeneration of renewable resources and ecosystems services that are essential for the survival and well being of humans.

From an environmental viewpoint, natural resources base also has ecological functions that keep the earth system as a living organism. This implies maintenance of cyclicity or equilibrium status of major biogeochemical cycles such as carbon cycle, nitrogen cycle and water cycle as well as energy balance of the earth system. Disruptions to these cycles or balances may lead to environmental conditions that are significantly different from the present environment in which the current society has developed. Such manifestations can be seen at small scale as increases of flood frequencies and temperatures in dense urban areas due to changes to water cycle and energy balance, or in large scale as climate change due to disruption to earth energy balance.

A sustainable ecology requires that our needs for environmental services can be met without damaging the sustaining natural system. Ecological security is defined as the status reflecting the threat to human living, health, basic rights, guarantee of secure life, necessary resources, social order and the ability to adapt to environmental change (IASA, 1989). Shi et al.,(2006) identifies biological security, environmental security and ecosystem security as three essential components for ecological security. Environment and ecosystem security refers to the structure, function and development of the ecosystem where ecosystem and social system can co-exist, in a way that both are capable of restoring their healthy status under certain stresses. Thus, the current ecological security concept has broadened to embrace the importance of ecosystem wellbeing regardless of its direct influence to human welfare acknowledging the inter-dependence of human wellbeing with the planetary wellbeing. The concept of ecological security has evolved to be more eco-centric than the traditional environmental security and human security concept by incorporating the scientific and conservationists concerns for the conservation of ecosystem for itself. This definition also is close to the ecological economists description of sustainability discussed earlier. The major achievement of sustainable development concept is to bring close natural and social sciences (Daly, 1980) and its ability to serve as a grand compromise between those who are principally concerned with nature and environment, those who value economic development and those who are dedicated to improving the human condition (Kates et. al, 2005).

## Sustainability Science

What type of education is needed to achieve these development objectives? The traditional form of knowledge production has been organized in academic disciplines where the interest is primarily to produce knowledge on the interaction of physical and human components of nature. For this purpose universities have been organized in faculties and departments. The reward system, career system and quality control by peer review are contained within the disciplinary boundaries. On the other hand, as modern society increasingly demands application-oriented knowledge and the usability of scientific knowledge, integration of knowledge from various disciplines is becoming of vital significance. The 2001 World Congress "Challenges of a Changing Earth 2001" in Amsterdam organized by the International Council for Science (ICSU), the International Geosphere-Biosphere Program (IGBP), the International Human Dimensions Program on Global Environmental Change (IHDP) and the World Climate Research Program (WCRP) proclaimed the birth of a new academic field, namely sustainability science, with strong roots in the environmental aspects of the sustainability concept (Kates et. al, 2001).

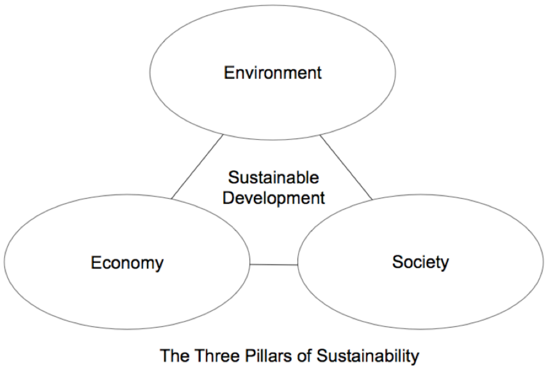
Sustainability science has been proposed as a new discipline to integrate approaches and knowledge from different disciplines to solve interconnected global problems. Sustainability science differs from normal science in that it seeks a complimentary truth to traditional form of knowledge generation. Its objective is to ensure the sustainability of earth system. This means we need to have not only the knowledge related to earth system and its processes but also the competency to assess the consequences of knowledge application on the sustainability of earth system. Search of sustainable solutions to global problems requires new methodologies that bring together the three pillars of sustainability; environment, society and economy. We also need to consider the sustainability of earth system processes, especially the global water, energy and geochemical cycles and their stability needed to sustain life on earth.

## Sustainability Education: Challenges and Opportunities

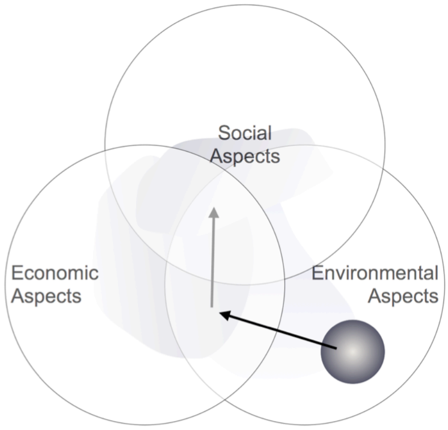
The need to integrate across disciplines is accepted broadly as a requisite for sustainability and new education and research methodologies are needed to operationalize such integration. The Institute for Sustainability and Peace of the United Nations University (UNU-ISP) was established in 2009 to pursue the study of Sustainability and the author was appointed as the Academic Director for the graduate program that consisted of a Masters and a Ph.D. program to address sustainability issues and conduct research on based on sustainability principles. The following sections briefly describe the educational program developed and implemented in the graduate programme of the UNU-ISP.

*Integration across disciplines: Research*

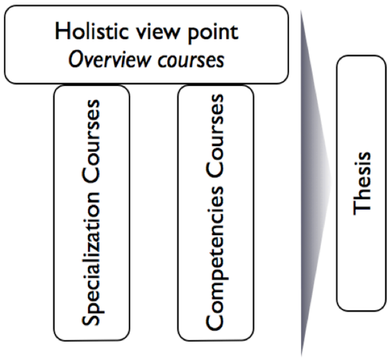
Several models that link environment, society and economy to achieve sustainable development (figure 1(a)) has been adopted in the UNU-ISP research programme to seek solutions for a given problem(One such approach is shown in figure1(b). Here at first a set of feasible solutions for a given problem is obtained through environmental analyses. Then a subset of those solutions is identified which also satisfy economic constraints and finally solutions that pass the test of social acceptance are selected for implementation. In this approach, one may start looking for solutions in any domain and finally try to arrive at a common feasible or acceptable area.




(a) Sustainability Focus




(b) Research Methodology




(c) Educational Program Components

Figure 1 Research and Education in addressing sustainability

*Integration across disciplines: Education*
Similar to research across disciplines, developing educational programs across disciplines is a challenging task. Providing a broader understanding across disciplines is desirable, but it may produce graduates who understand issues, but

not experts to carry out research and implement projects. To strike a balance between broad overview education and the specialization required, the UNU-ISP M.Sc. program consists of three components that provide;

- A broad holistic view point, through *overview* courses
- A deep understanding of a particular field through *specialized* courses
- A set of courses to provide skills needed to implement research, through *competency* courses

The outline of the program is shown in the figure 1 (c).

*Integrating capacity development, education and research*

In order to be effective, capacity development should target a range of stakeholders and actors who are involved in development processes and whose cooperative actions are essential for the sustainability of the development efforts. To be effective UNU-ISP, capacity development programs cover the following three major target groups;

- Researchers and Postgraduate sector: This sector is the most important segment of a country that has the capacity and the resources to absorb new knowledge and customize it to local conditions. Educational programs should endeavor to strengthen and engage the research/postgraduate sector in contemporary problems.

- Professionals/Practitioners: Professionals and practitioners need to be introduced to new methodologies and tools as well as emerging and modified design standards. In order to be effective, it is necessary to design programs that can be conducted in a short time and can reach a wide audience.

- Administrative / Local governments: The final target group is the administrators and decision makers including local government officials, who need to have an over view of the technology and science as well as its use. Key messages should be developed for this target group.

It is important to provide opportunities for the above target groups to work together. Capacity development programs can be designed to address this issue by enabling collaboration among stake holders by conducting group oriented training where participants come from each stakeholder group who would

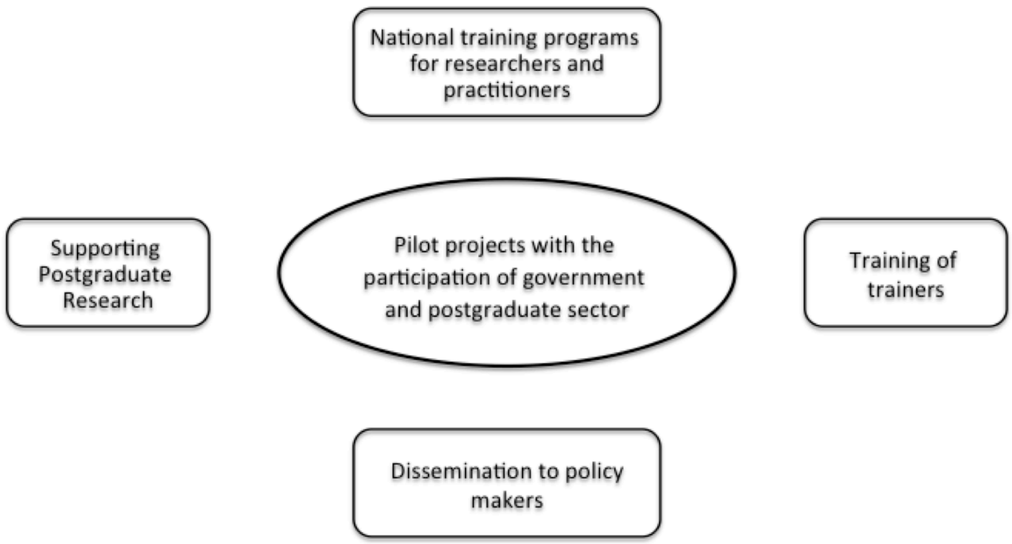





Figure 2 Integrated capacity development framework

continue to work together after the training programs providing the long term commitment required for sustainable solutions. One of the approaches adopted at UNU-ISP is to develop pilot demonstration projects, which also act as field stations that promote such collaboration among the postgraduate, government and policy-making communities through applied research work. These demonstration projects provide the venue to customize knowledge and methodologies from the global scale to local scale. This concept is demonstrated in figure 2. To be effective such programmes should be tightly coupled with capacity development programs and should run for 3-4 years. A case study of this approach with 8 demonstration projects conducted in four countries is described detailed in Herath and Kawasaki (2012a).

## Case Study

*Background*

A research conducted in the M.Sc. program on managing urban storm drainage in rapidly urbanizing areas is presented here to illustrate this approach to seeking sustainable solutions. It is well known that urbanization increase the maximum flood peak in a fixed period of time due to two reasons. The first is the increase of impervious areas that prevent infiltration of rainwater and produce a larger runoff volume from a given rainfall amount. This change is captured by runoff coefficient, which describes the ratio between rainfall to storm discharge. Its value may change from 0.3 in an un-urbanized natural state to about 0.6 or 0.7 in a densely urbanized area. The second mechanism to increase the peak discharge is the shortening of the rainfall duration required to produce a flood in the catchment after urbanization. Due to improved drainage works, the runoff can reach receiving streams in a short time and this enables a short duration rainfall compared to undeveloped state to produce a flood. The time to peak from the starting time of rainfall is termed 'time of concentration ($t_c$)' and if $t_c$ is reduced from 60 min to 20 min, the rainfall duration required to produce the peak flood discharge would also reduce from 60 min to 20 min. As the frequency of short duration high intensity rainfalls are much higher than the long duration high intensity rainfalls, the shortening of duration can increase the rainfall intensity significantly for the same probability of occurence. For example, an area experiencing a maximum rainfall of 50mm/hr over period of one hour with a return period of in one in five years will now receive 84 mm/hr intensity rainfall over a period of 20 min in the same return period of one in five years. The combined effects of the shortening of the time of concentration $t_c$ and the increase of impervious areas given by runoff coefficient, f, is summarized in figure 3. The y axis denotes ratio of the peak discharge after urbanization (Qu) compared with that prior to urbanization (Qn). X axis denotes the time of concentration of the catchment. It can be seen that with the $t_c$ reducing from 60 min to 20 min and the runoff coefficient increasing to 0.7 from 0.3, will produce peak discharges four times higher compared to the un-urbanized conditions.

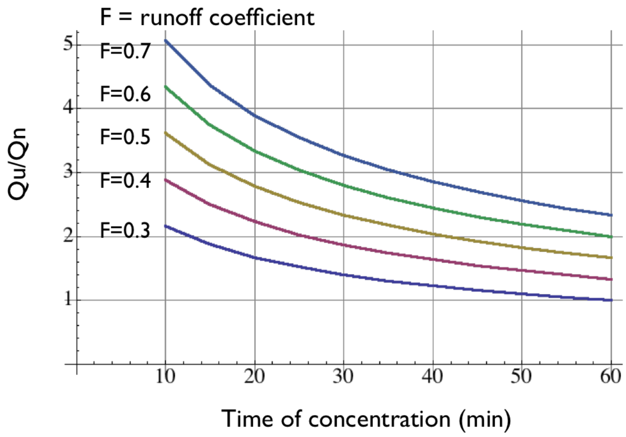



Figure 3. Increase of flood peaks due to urbanization for 1:5 year rainfall

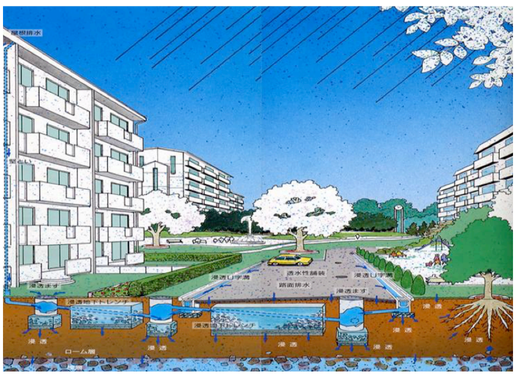


Figure 4 Use of infiltration trenches to collect and infiltrate rainwater in an urban housing complex

Managing these increasing flood peaks in urban areas has been a major challenge for almost all mega cities in Asia. Often it is difficult to expand river infrastructure to accommodate this increasing demand for flood discharge due to the existing infrastructure and property distributions. This requires exploring alternate ways of managing floods, such as underground facilities and source control also known as on site management. Some examples of onsite

Figure 5. Use of urban facilities and temporary flood control measures (courtesy: Association for Rainfall Storage and Infiltration Facilities (ARSIT))

management are the infiltration facilities and temporary retention in urban areas as shown in figures 4 and 5. The infiltration facilities provide the added environmental benefit of recharging the ground water. Due to reduction of infiltration rates by urbanization, ground water storage tend to deplete resulting in reduced base flow of urban stream flows that are fed by them. This in turn lead to deterioration of urban water quality as well as reduction of ground water resources available to the inhabitants. Through the infiltration systems the ground water gets recharged remedying the situation. More importantly, they can be designed to restore the local water cycle disrupted by the urbanization process. By restoring the water cycle we contribute to preserving water cycle and thus, earth-system sustainability.

*Flood reduction measures*

The study was carried out in a dense urban residential catchment of 2.3 $km^2$ area in the Tokyo Metropolitan area (Herath et.al., 2012). Current carrying capacity of the stream is for the maximum discharge from a one in five year return period of rainfall. In order to improve flood security the study first looked at the types of

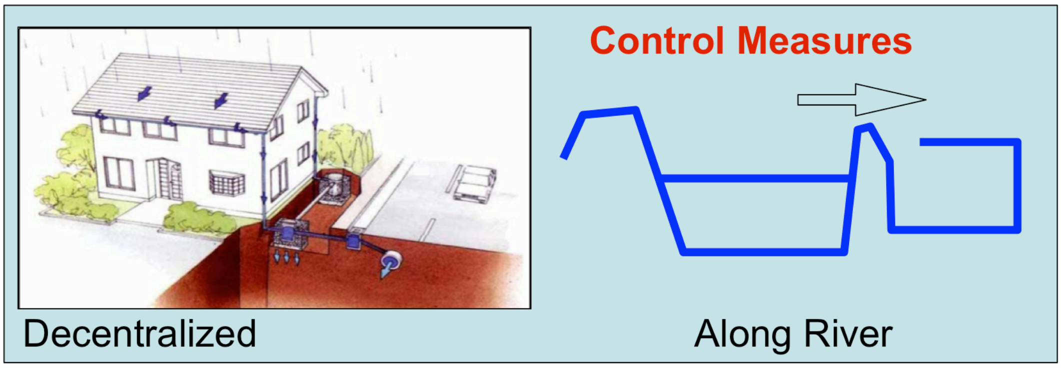



Figure 6. Two types of flood control measures considered in the basin

flood control facilities that can be utilized to increase the flood discharge capacity of the river to one in 10, 15 and 50 year return period rainfalls. There are two types of feasible flood control measures that can be installed to reduce the storm water discharge so that the flow within the river remains under its carrying capacity. One of them is the centralized underground reservoir along the river, which takes overflow of the stream discharge, and the other is an infiltration box installed at each household. The two types of feasible facilities are shown in the figure 6. For the use of infiltration boxes at each household, the residents need to carry out the installation, but the government provides a subsidy equivalent to 80% of the installation cost.

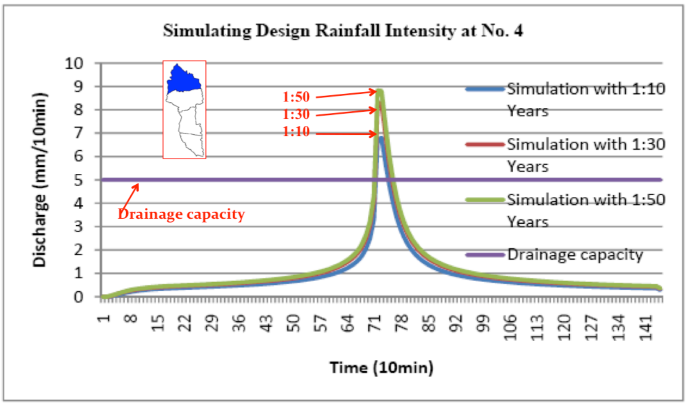



Figure 7. Flood discharge at different design rainfalls at upper end of the catchment.

As with conventional design, first the peak discharge for different design rainfall events are estimated through numerical simulations and compared with the actual drainage capacity of the stream. Figure 7 shows the peak discharges compared with the current capacity at the upstream area of the catchment for maximum 24 hour rainfall expected in different return periods. In the conventional design process flood control structures are designed to accommodate this excess discharge component. In this study, we estimate a range of feasible combinations of two types of facilities, i.e., the extent of centralized underground storage facilities needed is estimated for different degree of infiltration facilities installations to achieve the flood control goals. Figure 8 shows such a set of feasible combinations for the upstream area of the catchment.

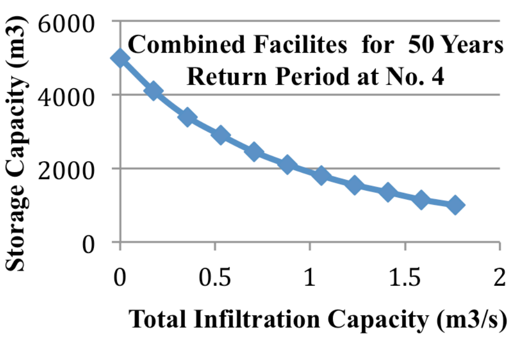



Figure 8. Feasible combinations of storage and infiltration facilities to achieve target flood control levels.

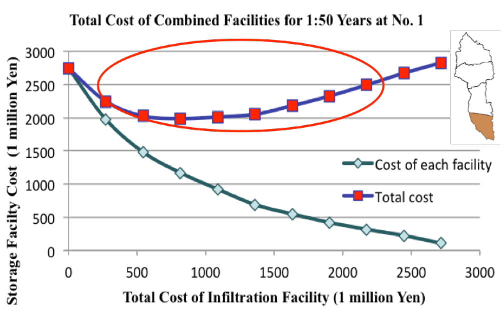



Figure 9. Total construction costs for various combinations of storage and infiltration facilities.

In order to identify the least cost solutions, we next estimate the total construction cost for each combination of two types facilities shown in figure 9. It can be seen that least construction

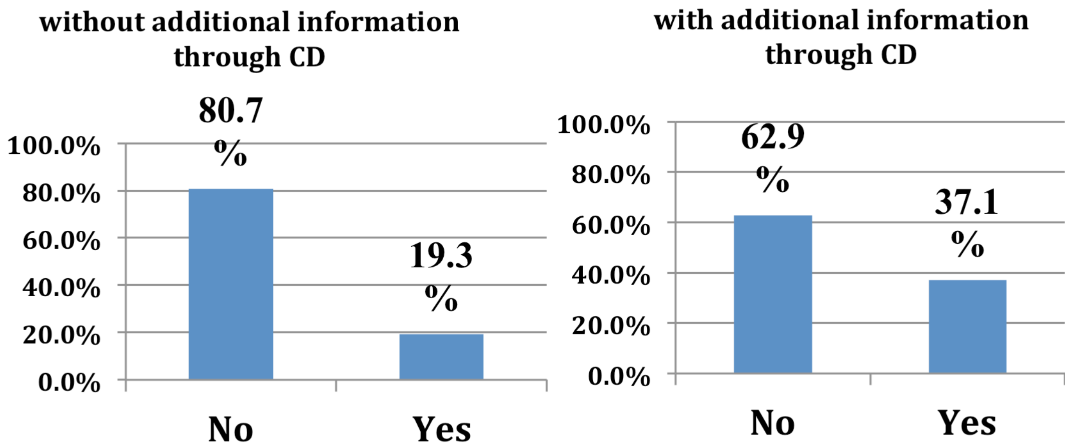



Figure 10. Willingness to install infiltration facilities according to survey results

cost is achieved when about 70% of flood control is taken by the central systems and the remaining 30% by the distributed infiltration systems. To implement such a scheme, it is necessary that a significant number of residents in the study area should agree to install infiltration systems. By analyzing different scenarios it is observed that infiltration systems need to be installed in about 20-30% of

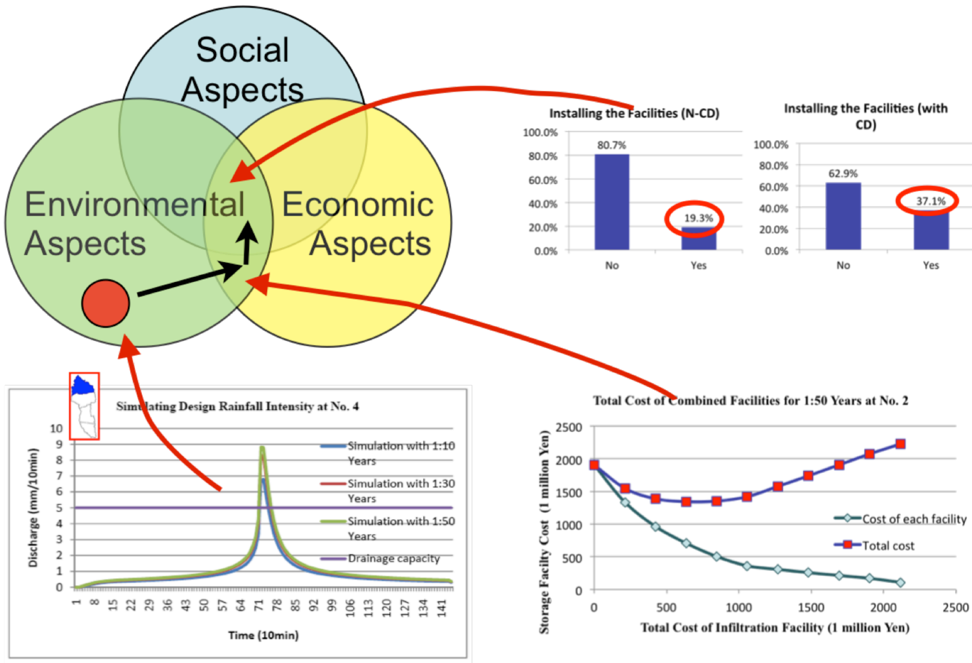
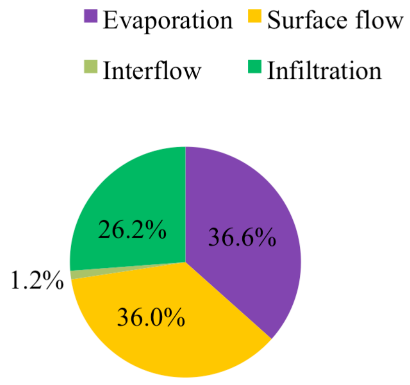



Figure 11. Search for sustainable solutions involving distributed and centralized control measures

residential areas to meet desired distribution between the two types of control facilities. A household survey was carried out to understand the willingness of the residents to participate in this distributed flood control program. To further analyze how such a decision may be influenced by the knowledge that infiltration systems help restoring the local water cycle and help improving the local environment, a CD describing the adverse impacts of urbanization on water cycle and how it may be restored through water retention and infiltration was included in the questionnaire survey of 50% of the respondents. The results of the survey are summarized in Figure 10. 37% of the respondents who were informed of the environmental benefits of infiltration systems were willing to participate in the program, compared with less than 20% of the respondents who were only asked to support for flood control. Both groups were informed of the subsidy. Thus we find that a sustainable solution that satisfy the all three pillars of sustainability can be found provided awareness of the society is raised on the environmental concerns. Further more, the approach adopted here can be used in conventional engineering design carried out to achieve a particular design objective. Here we try to identify a feasible solution from a set of solutions that is in conformity with a broader constraint ensuring the sustainability of the earth system. The flow of the analysis is summarized in figure 11.

For future design we need to refine this approach and adopt both sustainable development objectives and earth system sustainability as our design criteria. Managing the water cycle through the distributed flood control systems helps us to adjust the major components of the water cycle. The water cycle components for the sub catchment 4 in study area is shown in Figure 12. The direct runoff constitutes 36% of the total rainfall where as 27% percolates to the soil, recharging the ground water. The maximum possible installation of infiltration systems in the sub catchment will modify the current water cycle components as shown in figure 13. Therefore if we prioritise maintaining integrity of water cycle among the design criteria, first we need to assess the pre-urbanised water cycle. Then we need to assess the current water cycle (shown in figure 12) and do scenario analysis for various distributed approaches that would move the current altered water cycle towards the natural state. In the present study the maximum recovery possible for the studied types of installations is shown in figure 13.



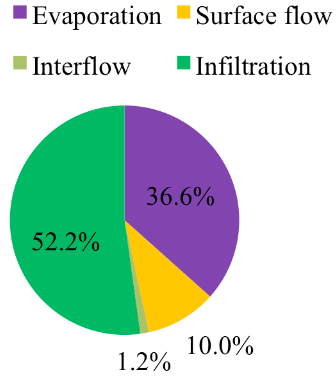




Figure 12. Without infiltration facilities

Figure 13 With infiltration facilities

Such approaches not only enhance the resilience of communities, but also that of the earth system. At community levels we need to ensure sustainability by addressing three pillars of sustainability. At the global level, we need to consider the planetary boundaries and the integrity of major biogeochemical cycles such as carbon cycle, nitrogen cycle and water cycle as well as energy balance of the earth system as design constraints. If water cycle focused design approaches are adopted in city planning from an early stage, we may avoid unacceptable levels of floods as well as ground water depletion, improved water quality and a stable water cycle.

**Conclusions**

Rapid global changes and growing population demands bring unprecedented challenges in meeting the resource needs challenges of present and future generations within the carrying capacity of earth so that not only the present generation but also the future generations can meet their needs. The solution to these problems converges in integration of disciplines at different levels under the broad umbrella of sustainability. Integration of different disciplines and methodologies brings in new challenges as well as opportunities. New educational and research programs based on sustainability science, where integration of different disciplinary approaches provides pragmatic solutions need to be developed and promoted. In adapting to rapidly changing environmental and social context of these problems, it is necessary to recognize localism, that is incorporating local characteristics in the solutions, is vital to make them sustainable. Postgraduate sector can be the ideal platform for disciplinary integration for sustainability and rapid dissemination and customization of useful global knowledge to local conditions, especially in the developing countries. Our conventional design approaches to infrastructure and products needs to be replaced with new methodologies that explicitly consider the sustainable design principles as well as global sustainability constraints.

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