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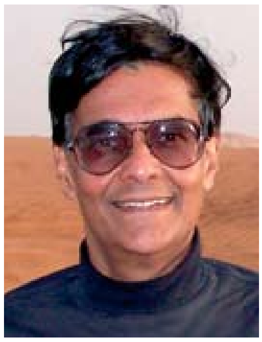

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# Integrated solutions for water, sustainable development and climate change issues: Applying the sustainomics framework

This paper practically addresses major global challenges involving water, sustainable development and climate change, which are interlinked. Water and climate change issues undermine development prospects and worsen existing problems, especially poverty. A longer term vision should go below the surface level development indicators, addressing deeper issues systematically and focusing on both immediate drivers and underlying pressures. The most effective approach is to integrate climate change and water policies into a national sustainable development strategy, using the sustainomics framework for "making development more sustainable", with balanced and integrated analysis from three main perspectives – social, economic and environmental. Several applications of practical tools are shown at the global, national and local levels.

**Keywords:** sustainable development, climate change, water, sustainomics

## Introduction

Water problems are closely linked to the two major challenges of the 21st century – sustainable development and climate change. Water and climate change issues undermine development prospects by worsening existing problems, including poverty, hunger and illness (IPCC, 2007, 2008; IARU, 2009). Current solutions are piecemeal and inadequate. The novel argument in this paper is that these issues can, and must, be addressed together. The sustainomics framework for "making development more sustainable" is described, which provides the most effective solution – by integrating water and climate change policies into a national sustainable development strategy (Munasinghe, 2007). The approach relies on a balanced and integrated analysis from three main perspectives – social, economic and environmental. A longer term vision of sustainable development is set out, that goes below surface level indicators of development, addressing deeper issues systematically and focusing on both immediate drivers and underlying pressures. Several case studies at the global, national and local levels illustrate practical applications of the methodology.

### Water and development

Water is essential for human activity – for drinking and sanitation, agriculture, hydropower, fisheries, industry, etc. (UNICEF/WHO, 2005). It is also crucial for ecosystem services, which support life on the planet (MA, 2005). Key issues in the water sector include; meeting growing water needs for development and poverty alleviation, mobilising funds to meet rising costs, maintaining financial viability, improving governance, ensuring diverse, affordable and reliable water services, protecting the environment, and balancing competing uses (World Bank, 2005).

Safe drinking water is unavailable to 900 million people, while over 2 billion lack adequate sanitation (World Bank, 2005). Over US$11 billion per year is needed to meet the drinking water and sanitation targets of the Millennium Development Goals (UNICEF/WHO, 2004). In 2001, two million people died from infectious diarrhoeas – two thirds were children under five, and most deaths were preventable (UNICEF/WHO, 2005). Poor people living in the slums often pay five to ten times more per litre of water than wealthy people living in the same city (UNDP, 2006) As incomes rise, urban-industrial water demand increases, often leading to competition with rural-agricultural users.

Photo: Gety Images

Water scarcity exacerbates other development problems among the 3 billion people who survive on less than US$2 per day and almost a billion who are malnourished – many of them children. Two billion do not have access to electricity, while billions are also sick, exposed to environmental degradation (air, land and water), lack shelter and are vulnerable to disasters (IPCC, 2008; UNDP, 2009; Alcamo et al., 2007).

## Climate change – risk multiplier

Climate change is a major risk multiplier, systematically worsening all other problems. The latest scientific evidence indicates that global warming is unequivocal and almost certainly caused by increased greenhouse gas (GHG) emissions from post-industrial human activities (IPCC, 2007; IARU, 2009). Global warming is already worsening water-related problems. Climate change will likely intensify into the foreseeable future, with severe consequences for the inhabitants of planet Earth.

The IPCC (2007) comprehensively describes past and present trends. For over 10,000 years, atmospheric carbon dioxide concentrations were stable at 275 parts per million by volume (ppmv). However, following the industrial revolution, these concentrations rose rapidly, now exceeding 385 ppmv. During the past 100 years, this excess CO2, together with other minor GHG, like methane and nitrous oxide, have acted as a blanket to trap excess solar radiation and warm the planet's surface an average of 0.75 °C, through a process called climate forcing. There is other convincing evidence of accelerating climate change – including a systematic rise in the mean sea level (17 cm during the past century), melting of ice in polar areas and glaciers, increased damage caused by extreme weather events, less precipitation in dry areas and more in wet areas, and significant changes in ecosystems and animal behaviour.

If emissions are not curbed, by 2100, $CO_2$ concentrations will be about twice the pre-industrial level (i.e. 550 ppmv). Even if GHG emissions were sharply cut, temperatures would still rise by at least 1.5 °C by 2100. Increasing scientific evidence suggests that 2 °C (corresponding to 400–450 ppmv) is the "dangerous" risk threshold, which implies that global emissions of greenhouse gases need to peak by 2020 at the latest. The post IPCC-AR4 data emerging during the past three years indicates that the situation is indeed worsening (IARU, 2009). By 2100, the average global temperature will increase by over 3 °C above current levels, and the mean sea level will rise at least half a metre. Extremes of temperature and precipitation will worsen, and the melting of ice will accelerate. Weather events will also become more extreme – especially tropical cyclones and heat waves.

Groups most vulnerable to climate change impacts are the poor, elderly and children, including those living in rich countries (IPCC, 2007). The most affected regions will be the Arctic, sub-Saharan Africa, small islands, and Asian megadeltas. High risks will be associated with low-lying coastal areas, water resources in dry tropics and subtropics, agriculture in low-latitude regions, key ecosystems (like coral reefs) and human health in poor areas.

Such impacts make many of the Millennium Development Goals (MDGs) even more difficult to achieve (MDG, 2009). Major MDGs include: eradicating extreme poverty and hunger, achieving universal primary education, promoting gender equality and empowerment, reducing child mortality, improving maternal health, combating HIV/AIDS, malaria and other diseases, ensuring environmental sustainability and building a global partnership for development.

## Climate–water interactions

Climate change will have severe adverse impacts via the hydrological cycle, especially on the vulnerable poor (IPCC, 2007). More droughts and floods are already causing social instability, food insecurity and long-term health problems (especially in growing mega-city slums). Sea-level rise and worsening storms could affect hundreds of millions by 2050.

The two human responses to climate change are adaptation and mitigation. Making development more sustainable by mainstreaming adaptation and mitigation measures into a sustainable development strategy is considered the most effective solution (Munasinghe, 2002; IPCC, 2007; IARU, 2009). Adaptation refers to adjustments in human and natural systems that reduce vulnerability to climate stresses, moderate damage and enhance benefits – such as building higher sea walls, or strengthening water systems against droughts. Mitigation covers activities that reduce GHG emissions, which will worsen future climate change – such as reducing energy use, halting deforestation, or absorbing atmospheric $CO_2$ by growing biomass.

Water and development are interlinked with both adaptation and mitigation. For example, more sustainable water management will make adaptation and mitigation more effective, by enhancing agriculture and forestry. Conversely, many adaptation and mitigation policies can help make water use and overall development more sustainable. Effective longer-term response measures include strengthening water system resilience, building the adaptive capacity of vulnerable socioeconomic and ecological systems and managing disaster risks. More data and analytical capability is crucial.

## Current global problems and ineffective solutions

In this section, key emerging global risks are analysed and shortcomings in present day remedies are highlighted, prior to presenting a sustainable development vision for the future. The world is currently facing multiple economic, social and environmental threats, where short-sighted policies enable a few people to enjoy immediate gains while the unsuspecting majority will pay huge "hidden" costs in the future. These threats can interact catastrophically, unless they are addressed urgently and in an integrated fashion, by making development more sustainable (Munasinghe, 2007, 2009). Piecemeal responses have proved to be ineffective, since the problems are interlinked.

### Economic, social and environmental risks

The economic collapse is the most urgent and visible global problem. An asset "bubble", driven by investor greed, rapidly inflated the value of financial instruments well beyond the true value of the underlying economic resource base. The collapse of this bubble in 2008 caused the global recession (OECD, 2009; Taylor, 2009). It is estimated to contain some $100 trillion of "toxic" assets (up to twice the annual global GDP).

Meanwhile, poverty and inequity continue to be major social problems, undermining the benefits of the rapid economic growth of recent decades, and excluding billions of poor from access to productive resources and basic necessities, like safe water and sanitation, food, energy, health care and shelter (World Bank, 2009). In 2000, the top 20% of the world's population by income consumed 60 times more than the poorest 20%. Poverty is now exacerbated by the economic recession, which is worsening unemployment and access to survival needs.

Finally, mankind faces major environmental problems because myopic economic activities continue to severely damage the natural resource base on which human well being ultimately depends (MA, 2005; UNEP, 2008). Climate change is the classic global manifestation of this threat, but equally serious issues are the degradation of local water, air and land resources. Ironically, the worst impacts of climate change will fall on the poor, who have very little responsibility for causing the problem (IPCC, 2007).

And what are our current policy priorities as we face these challenges? Governments have very quickly found about US$5 trillion dollars for stimulus packages to revive shaky economies (G20, 2009). However, only about US$100 billion per year is devoted to poverty reduction, and far less to combat climate change (World Bank, 2009). Furthermore, the recession has dampened enthusiasm to address more serious long-term poverty, climate and other environmental and social issues.

World leaders missed a golden opportunity to simultaneously address these multiple threats, by using the US$4 trillion dollars of stimulus funds more effectively. A much larger share should have been invested in the key areas of green resources and infrastructure, especially water (as well as agriculture, renewable energy, and transport), sustainable livelihoods and safety nets for the poor, and social development (typically education, health and safety), to stimulate the economy, increase employment, reduce poverty and protect the environment (including the climate). Instead, funds were used to protect current expenditures – especially wasteful subsidies and bank bail-outs that merely restored the failed status quo. The momentum for longer-term change was lost.

In the water sector alone, an investment of US$11–12 billion per year (a fraction of the stimulus funds) would have helped achieve the Millennium Development Goal 2015 targets for drinking water and sanitation (UNICEF/WHO, 2004). On average, every US$1 invested in water and sanitation provides an economic return of US$8, plus other benefits due to improved health, well-being and productivity.

## Long-term vision of sustainable development

Unless multiple global problems are addressed promptly, humanity faces a difficult future. A brighter alternative pathway is discussed below.

A longer-term vision is summarised in Table 1. The top row shows how our current focus on surface level indicators, like poverty, inequity, exclusion, resource scarcities and conflict, poor governance and environmental harm, is driven by powerful phenomena like globalisation and unconstrained market forces based on the "Washington Consensus". Problems are addressed myopically, in a reactive uncoordinated and piecemeal manner (the "silo" mentality). Therefore, present trends pose significant risks that could lead to a global breakdown, due to the ineffectiveness of governments seeking to cope with multiple, interlinked crises. Merely undertaking policy reforms to correct for market deficiencies would be inadequate to deal with these threats. Instead, deeper issues need to be addressed systematically (as described below).

The second row in Table 1 shows that an immediate transitional step forward is possible, by influencing key common drivers of change – consumption patterns, population, technology and governance. These drivers shape the main issues in the top row, and managing them will help address multiple issues in an integrated manner, controlling global trends and market forces.

Using known practical measures that make development more sustainable today, business and civil society could help governments move proactively towards the ultimate goal of sustainable development. This transitional step involves early action to overcome global inertia – specific measures using existing experience and tools are described below. To begin this process, a comprehensive practical framework called "sustainomics" was proposed at the 1992 Rio Earth Summit – see Box 1 (Munasinghe, 1992a).

The third row follows on from the successful implementation of the second (transition) row. Here, in coming decades our children and grandchildren could pursue their long-term goal of a truly global, sustainable development paradigm. They would need to work on deep underlying pressures linked to basic needs, social power structure, values, perceptions, choices and the knowledge base. Fundamental changes are necessary, driven by social justice and equity concerns through inspired leadership, a networked, multistakeholder, multi-level global citizens' movement, responsive governance structure, improved policy tools, advanced technologies and better communications (including the internet).

| | | | |
|---|---|---|---|
| **Main issues** | **Poverty, inequity, exclusion, conflict, environmental harm, climate etc.** | | **Present human responses**<br>Business-as-usual with high risks from unrestrained, myopic market forces (Washington consensus, globalisation, etc.)<br>Reactive: piecemeal, mainly government |
| **Immediate drivers** | **Consumption, population, technology, governance** | | **Practical transition step (Sustainomics)**<br>Making development more sustainable (MDMS), using systematic policy reform based on existing knowledge, to manage market forces.<br>Proactive: integrated govt., business, civil society |
| **Underlying pressures** | **Basic needs, social power structure, values, choices, knowledge base** | | **Long term goal (new SD paradigm)**<br>Fundamental global sustainable development transition through multi-level, multistakeholder, citizens networks, advanced policy tools responsive governance and better technologies.<br>Proactive: integrated civil society, business, government. |

Table 1. Current risks and future vision
Source: Adapted from Munasinghe (2007)

*Photo: BrandXPictures*

## Box 1: Sustainomics
## – a practical framework for action

Decision makers invariably are pre-occupied with immediate problems, like growth, poverty, water and energy scarcity, food security, disease, unemployment and inflation. New issues, like environmental harm and climate change, have also emerged. The transitional, integrative step 2 shown earlier in Table 1, would help to make decision makers more aware of the interconnections among these problems and show how to integrate solutions into a national sustainable development strategy. One promising approach to do so is "sustainomics" – developed over the past 20 years. It draws on the following basic principles and methods (Munasinghe, 1992a, 2002).

### Making development more sustainable (MDMS) for empowerment and action

First, making development more sustainable (MDMS) becomes the main goal. It is a step-by-step method that empowers people to take immediate action, which is more practical because many unsustainable activities are easy to recognise and eliminate – like conserving and recycling water. While implementing such incremental measures, we also continue parallel efforts to achieve long-term sustainable development goals. One key test for potential water and climate policies would be whether they would make development more (or less) sustainable.

### Sustainable development triangle with a balanced and integrated viewpoint

Policy issues need balanced and integrated analysis from three main perspectives – social, economic and environmental (Figure 1). Interactions among these three domains are also important. The economy is geared towards improving human welfare, primarily through increases in the consumption of goods and services. The environmental domain focuses on protection of the integrity and resilience of ecological systems. The social domain emphasises the enrichment of human relationships and achievement of individual and group aspirations. Climate change and water are linked to all three domains. First, economic growth drives water use and emissions that cause climate change, while water scarcity and climate change impacts will undermine future development prospects. Second, water availability and climate have severe social implications, worsening poverty and equity. Third, water stress and climate change will exacerbate ongoing ecological damage, while environmental harm (like deforestation) will worsen water scarcity and climate. Win–win options, which satisfy all three criteria, will best integrate water, climate and development. In other cases, judicious trade-offs would be required to resolve potential conflicts.

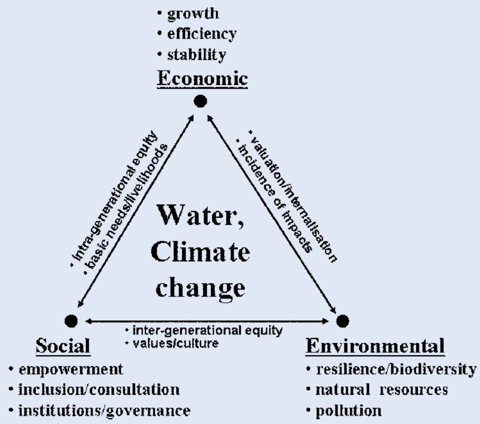


Figure 1. Water and climate change are interlinked with the economic, social and environmental dimensions of sustainable development. Source: Adapted from Munasinghe (1992a)

### Transcending conventional boundaries for better integration

A comprehensive analysis must transcend conventional boundaries imposed by discipline, space, time and stakeholder viewpoints and values. Trans-disciplinary analysis is needed to find innovative solutions to complex problems of water, sustainable development and climate change that cut across conventional disciplines. Spatial analysis must range from the local to the global – typically from the community to the transboundary river basin and planetary scales. The time horizon will extend to decades or centuries. Cross-stakeholder data sharing, transparency and cooperation (especially civil society and business working with government) need to be strengthened, by promoting inclusion, empowerment and participation. It is also essential to replace unsustainable values, like greed, with sound moral principles, especially among the young.

### Full cycle application of practical and innovative analytical tools

The sustainomics framework uses a variety of practical full cycle tools – both new methods and conventional ones. They are applied innovatively to encompass the full operational cycle from initial data gathering to practical policy implementation, monitoring and feedback. Furthermore, life cycle analysis of the entire value chain is required, from raw material extraction to consumer end use and disposal, based on economic, social and environmental perspectives. This will help identify areas where innovation can improve production sustainability, reform pricing and derive the full water and carbon footprints. It will not only identify the most desirable "win–win" policies that simultaneously yield economically, environmentally and socially sustainable paths, but also resolve trade-offs among water use and other conflicting goals. Practical analytical tools are described below.

## Applications

Some representative applications of sustainomics tools and approaches to the water resources, climate and development nexus, are summarised below. Many more case studies are provided in Munasinghe (2009).

### Global consensus on climate and development

Sustainomics principles can be applied at the global level, to coordinate stakeholders in all countries and reshape human activities on an unprecedented scale. But, sadly, current trends have fallen short of expectations. The 1992 UN Framework Convention on Climate Change (UNFCCC, 1992), accepted by over 190 countries, provided a promising start. By 2005, to implement the UNFCCC, 174 countries had ratified the rather weak 1997 Kyoto Protocol. It specified that by 2012, Annex I (industrialised) countries would collectively reduce their emissions 5% relative to 1990 levels, while Non-Annex I (developing) countries were exempt from emissions reductions. Unfortunately, the largest GHG emitter, the USA, rejected it. Global emissions have risen over 70% from 1970 to 2004, with major increases occurring since Kyoto.

The first principle of sustainomics (making development more sustainable), suggests how a long-term consensus might evolve, to help reconcile climate responses and development aspirations – this is essential for the transition described in Table 1. The evolution of such a consensus is shown in Figure 2. On this stylised curve of environmental risk against a country's level of development, poor nations are at point A (low GHG emissions and low GNP per capita), rich nations are at point C (high GHG emissions and high GNP per capita), and intermediate countries are at point B.

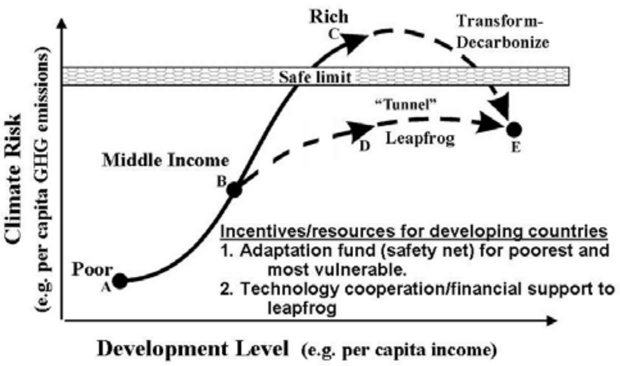


Figure 2. Integrating climate change into a sustainable development strategy by de-carbonizing and leapfrogging
Source: Adapted from Munasinghe (2002)

Equity and climate justice principles are relevant here. To date, over 80% of GHGs have been emitted by rich countries, and in 2005, the average per capita GHG emissions in industrial countries were four times greater than those in developing countries. But poor countries will be most affected by climate change. Thus, developing countries need to focus on vulnerability and adaptation, especially to alleviate poverty and protect their poor. Rich countries (which are better endowed financially and technically), should lead the mitigation effort and also assist poorer countries in both adaptation and mitigation work. Middle-income countries will need to join the mitigation effort over time, as they become richer.

The following elements are essential for a workable global compact on climate change:

- Industrial countries (already exceeding safe limits) should mitigate and follow the future growth path, CE, by restructuring their development patterns to delink carbon emissions and economic growth, thereby making their development path more sustainable;
- The poorest countries and poorest groups must be provided an adaptation safety net, to reduce vulnerability to climate change impacts;
- Middle-income countries could adopt innovative policies to "tunnel" through (along BDE – below the safe limit), by learning from the past experiences of the industrialised world;
- Developing countries should be encouraged (with technical and financial assistance) to simultaneously continue to develop (and grow) more sustainably, by following a growth path that is not only less carbon-intensive, but also reduces vulnerability to climate change impacts.

Recently, despite major expectations, the Copenhagen UN Climate Summit in December 2009 produced another weak, non-binding statement. Significant progress will be needed in the coming years to address the four points set out above.

#### Global adaptation response

Pre-planned adaptation is especially effective in the case of coastal areas threatened by sea level rise, flooding and storms (IPCC, 2007). If global warming reaches 2 °C and present expenditures on coastal protection remain constant, models indicate that about 55 to 90 million more people per year will be affected by 2080. However, these numbers may be drastically cut down to less than 10 million, by simple measures that involve marginal increases in annual coastal protection spending, matching GDP growth rates.

### National level applications

At the national level, action is facilitated by the practical tools of sustainomics including macro- and sector modelling, environmentally adjusted national income accounts, poverty analysis, water modelling, sustainable pricing (see Box 2) and the Action Impact Matrix (AIM – described below). At the project level, other useful methods are available for sustainable development analysis – like cost–benefit analysis, multi-criteria analysis and environmental and social assessment. At all levels, the choice of appropriate sustainable development indicators is also vital. The range of policy instruments includes pricing, taxes and charges, regulations and standards, quantity controls, tradable permits, financial incentives, voluntary agreements, information dissemination and research and development.

#### Macroeconomic, water and sustainable development analysis

A recent example analysing national macro-policies shows the complex trade-offs involving the second principle of sustainomics (the sustainable development triangle). In West Africa, macroeconomic–environmental studies have shown that deforestation was accelerated by trade policies promoting timber exports and rapid aggregate economic growth, combined with imperfections like, subsidies for land-clearing (policy distortion), and open access forests (market failure) (Rowe et al., 1992; Munasinghe, 1996; Gbetnkom, 2005). This exacerbated rural poverty, degraded watersheds and ecosystems, increased GHG emissions and undermined adaptation. Such imperfections make private (market) decisions deviate from socially optimal ones.

The problems of deforestation, watershed degradation and ecosystem damage were addressed by implementing complementary measures (like eliminating land-clearing subsidies and enhancing forest protection) – most importantly, without reversing the macro-policies that promoted growth and reduced poverty. In Figure 2, suppose the vertical axis represents watershed degradation (instead of carbon emissions). The highly peaked path ABCE could result from economic imperfections and environmental externalities. Corrective policies would help to reduce such distortions and leapfrog through the sustainable tunnel BDE. Such a tunnel path is also more economically optimal (e.g., like a "turnpike" growth path).

## Box 2: Sustainable water pricing

Sustainable water pricing uses the three elements of the sustainable development triangle (Munasinghe, 1992b).

First, it would be economically efficient to set water prices at long run marginal cost. This applies mainly to "blue water" used by humans, drawn from accessible lakes, rivers, aquifers etc. (Rockström et al., 2009).

Second, adding environmental externality costs (appropriately valued), including pollution taxes, would further reduce water use. This component of water pricing applies to "green water", diverted from precipitation and the soil, which is normally used by plants (Rockström et al., 2009), and to "brown water", which is polluted by industrial and agricultural wastes (Munasinghe, 1992b).

Third, from the social viewpoint, it would be equitable to provide subsidised water prices or lifeline rates targeted to the poor who cannot afford to pay the full price for their basic water needs, and to fund adaptation of those who suffer adverse impacts. This refers to "red water" that supplies the basic human needs for drinking and hygiene (Munasinghe, 1992b). Otherwise, simply raising prices would become an inequitable, unethical and ultimately unsustainable solution – that is, a way of rationing water and reserving it for the rich, while worsening the plight of the poor. This same argument would apply to carbon taxes and climate change.

### Water sector applications

#### Action Impact Matrix (AIM)

Among the various sustainomics tools, the Action Impact Matrix (AIM) is a unique method that helps to practically integrate water, climate change and sustainable development (Munasinghe, 2007). This approach has been used successfully in a number of countries during past decades. It helps to identify and prioritise issues arising from the two-way interaction: how (a) the main national development policies and goals affect (b) the key adaptation and mitigation options relating to water; and vice versa. It also determines the priority policies and strategies in economic, environmental and social spheres that will help implement integrated measures to address water, development and climate change issues.

The AIM methodology relies on a fully participative stakeholder exercise. Between 10 and 40 experts are drawn from government, academia, civil society and the private sector – representing relevant disciplines and sectors. They usually interact intensively over a period of two days to build a preliminary AIM. This participative process is as important as the product (that is, the matrix), since important synergies and cooperative, team-building activities emerge. The collaboration helps participants to better understand opposing viewpoints, resolve conflicts, promote cooperation and ownership, and facilitate the implementation of the agreed policy remedies.

Figure 3 shows a typical AIM summarising the effects of key climate change vulnerabilities, impacts and adaptation (columns 1 to 10) on the main national goals and policies (rows A to G) in Sri Lanka during 2007. The first status row (S0) indicates that natural variability already has an impact on the vulnerabilities. The second status row (S1) shows how climate change impacts will further affect each column – for example, in column 1 impacts on agricultural production will worsen from -1 (low harmful) to -2 (moderately harmful) due to climate change.

**Notation**
+ Beneficial
- Harmful
3 High
2 Moderate
1 Low

| | Key Vulnerabilities, Impacts and Adaptation (VIA) | (1) Agricultural Output | (2) Hydro-power | (3) Deforestation | (4) Biodiversity (flora & fauna) | (5) Wetlands & Coast Ecosys. | (6) Water Resources | (7) Poor Communities | (8) Human Health | (9) Infra-structure | (10) Industry & Tourism |
|---|---|---|---|---|---|---|---|---|---|---|---|
| S0 | Status (Nat. Variability) | -1 | 0 | -2 | -1 | -1 | -2 | -1 | 0 | 2 | 2 |
| S1 | Status (+CC Impacts) | -2 | -1 | -2 | -2 | -2 | -3 | -2 | -1 | -1 | -1 |
| | Dev. Goals/Policies (with CC Impacts) | | | | | | | | | | |
| A | Growth | -1 | -1 | -1 | -1 | -1 | -2 | -2 | -1 | -1 | -1 |
| B | Poverty alleviation | -2 | 0 | -1 | -1 | -1 | -2 | -2 | -2 | -1 | -1 |
| C | Food Security | -3 | 0 | -1 | -1 | -1 | -3 | -1 | -1 | 0 | 0 |
| D | Employment | -1 | 0 | -1 | 0 | -1 | -2 | -1 | -2 | -1 | -2 |
| E | Trade & Globalisation | -2 | -1 | 0 | 0 | 0 | -1 | -1 | 0 | -2 | -1 |
| F | Reduce Budget Deficit | -1 | -1 | 0 | 0 | 0 | 0 | 0 | -2 | 0 | -1 |
| G | Privatisation | 0 | 1 | 1 | 0 | 0 | 1 | 0 | 0 | -1 | -1 |

Figure 3. Effects of climate change vulnerabilities, impacts and adaptation on development policies and goals in Sri Lanka. Source: Author

When scanning the entire matrix, the cells with values of -3 or -2, which indicate the more adverse effects, should be given greater priority, while cells with values of 0 or 1 may be ignored. Thus, the value of -3 in cell C1 indicates that climate change will be very harmful to food security via the agriculture sector. Similarly, we note that cell C6 also has a value of -3, showing that the lack of water resources will also threaten food security. The AIM is built using a spreadsheet, with each cell hyperlinked to a separate sheet describing details of why such values were given, including literature citations – for example, the detailed description for cell C1 describes all major crops in Sri Lanka, under different temperature and rainfall conditions.

In summary, the food security row, C, raises the alarm, because both declining agricultural production and water resource shortfalls will have highly harmful impacts (matrix cells C1 and C6 respectively). Thus, food security issues should have a high priority, in subsequent policy analysis.

### Water, agriculture and food security

Accordingly, a more detailed study of water, food security, and agriculture was carried out using a Ricardian agriculture model, to identify how past output changes in important crops, like rice, tea, rubber and coconut, had depended on natural variations in climate – mainly temperature and rainfall (Munasinghe, 2007). Then, a downscaled regional climate model was used to make detailed temperature and precipitation predictions specific to Sri Lanka, up to the year 2050. The combined results of both models showed that climate impacts on future rice cultivation would be negative and significant (almost a 12% yield loss by 2050) – affecting poor farmers in the dry zone of Sri Lanka, where incomes are lowest. Meanwhile, some areas in the wet zone, where tea is grown and incomes are higher, would experience gains (a 3.5% yield increase by 2050).

These findings raised several important policy issues.

- Rice is the staple food in Sri Lanka and a large portion of the population depends on rice farming. Thus, adaptation measures are essential to protect national food security, protect livelihoods and reduce the vulnerabilities of the rural poor in the dry zone.
- The differential impacts of climate change on poor farmers and richer landowners have income distribution and equity implications that also need to be addressed.
- Population movements from the dry to the wet zone are a potential demographic risk that policy makers need to deal with early.

## Disaster vulnerability and social capital: comparing impacts of the Asian tsunami and hurricane Katrina

The Sri Lanka AIM also identified serious coastal zone vulnerabilities and impacts on poverty alleviation goals (matrix cell B5 in Chart 6), due to sea level rise and storm surges. The 2004 Asian tsunami (although not climate related) had many similar effects. The tsunami and hurricane Katrina struck within 9 months of each other. Despite many differences, a comparison of the two disasters provides useful lessons about the social dimensions of the sustainable development triangle (see Box 1), and the key role of social capital in increasing community resilience against disasters (Munasinghe, 2007).

### Asian tsunami

The December 2004 Asian tsunami, triggered by a Richter scale 9 magnitude earthquake off the coast of Indonesia, was the most devastating disaster in modern history, killing over 250,000 people in South and East Asia. In Sri Lanka, about 35,000 people were killed (one in every 570 persons), and over half a million were displaced (one in every 40 persons). This was a catastrophic blow to a small developing country of around 20 million people, with a per capita income of barely US$1000 per year.

For many weeks, the government was overwhelmed and civil breakdown was predicted. Fortunately, civil society in Sri Lanka proved remarkably resilient and helped to hold the country together – apparently, the social capital embedded within traditional communities in affected areas and throughout the nation, played a crucial role. After several months, government relief efforts and assistance pouring in from abroad took on the major burden of relief and recovery, although civil society continued to play a significant role.

### Hurricane Katrina

The story of New Orleans after hurricane Katrina struck (in late August 2005), was somewhat different. Damage from Katrina to the Gulf Coast was about US$100 billion, making it the costliest hurricane in U.S. history. The storm killed about 1840 people (less than 2 per 1000 persons of the 1.3 million population) – far fewer than in Sri Lanka. Also, unlike the tsunami, which wreaked damage within a few hours, Katrina built up over a week (23–29 August) and there should have been sufficient time to prepare – given the advanced early warning systems, and technological and economic resources available. Nevertheless, a large city within a country of 300 million (with a 2006 per capita income of US$44,000 per year), suffered a major social breakdown involving looting and violence. Subsequent relief and recovery efforts have sought to remedy immediate problems, but the vulnerability of social structures raises more serious long-term questions about the lack of social capital.

Most disaster studies focus on economic and environmental factors, but the sustainomics framework highlights the role of the social dimension. Further research is ongoing regarding the factors underlying social resilience, and methods of making development more sustainable by building social capital to complement the traditional restoration of economic and environmental capital, and reduce overall disaster vulnerability.

## Simple water filtration method for cholera prevention in Bangladesh

### Economic valuation and multi-criteria analysis (MCA)

There are many practical techniques to placing a monetary value on environmental impacts. Multi-criteria analysis (MCA) is another complementary sustainomics tool that may be applied, especially when the economic valuation of social and environmental effects is problematic (Munasinghe, 1992a, 2007). It allows policymakers to look at all three elements of the sustainable development triangle (economic, social and environmental) in a balanced manner – in large part, by quantifying and displaying trade-offs in differing units of measurement, since some impacts cannot be measured solely in monetary terms.

### Water contamination and cholera

Scarcity of safe drinking water is a global problem that will worsen with poverty, population growth and extremes of flooding and drought due to climate change. Cholera is a waterborne diarrheal disease spread by drinking unsafe water, which kills many children in developing countries. About 5.5 million cases of cholera occur annually.

In Bangladesh, most villagers depend on untreated surface water for drinking. During the summer, aridity increases the abundance of the Vibrio cholerae (VC) bacterium which causes cholera (Sack et al., 2003). During monsoon flooding, wells are submerged, sanitary latrines get flooded, and contamination of drinking water by VC bacteria also leads to cholera outbreaks. Water purification by boiling or chlorination becomes difficult under such conditions. Thus, as extremes of flood and drought increase with climate change, cholera epidemics will become more serious.

A simple, cheap and socially acceptable method was devised that removes 99% of VC attached to plankton, by filtering contaminated water using four layers of old sari cloth. Tests with 15,000 villagers showed that 90% of the population accepted the sari filtration system in their daily lives, and the cholera incidence was about half the rate suffered by a control group (who did not use filtering). Sari filtration provided major health benefits, while satisfying sustainomics criteria – low economic cost, socio-cultural acceptability and environmental soundness, while being readily accessible under extreme weather conditions.

### MCA

Conventional water project evaluation uses cost–benefit analysis (CBA), where all impacts are valued in monetary terms. However, when environmental and social effects cannot be easily valued, multi-criteria analysis (MCA) is attractive.

Figure 4 uses MCA to assess our simple sari-based water purification method within the SWAMP framework. Outward movements along the axes trace improvements in three indicators – economic efficiency (net monetary benefits), social equity (improved benefits for the poor), and environmental protection (reduced water pollution). Triangle ABC shows the existing situation. Economic harm occurs (loss of earnings, medical costs, etc.), because of rising morbidity and mortality rates. Social equity is low because the poor are most affected, while environmental pollution is also bad. Next, triangle DEF indicates a "win–win" option with the simplified sari filtration technique, in which all three indices improve. Economic losses fall due to better health. Social gains accrue to the rural poor, especially women and children. Environmental benefits arise from cleaner water.

After realising such "win–win" gains, further improvements may require tradeoffs. For example, triangle GIH suggests that a better water supply (e.g. wells and surface water providing purified, pipe borne supply, or nanotechnology-based filtering techniques) may yield further environmental and social benefits, but with increased economic costs. After adopting the clearly desirable "win–win" move from ABC to DEF, shifting further from DEF to GIH, will require difficult tradeoffs among the three criteria. However, one may narrow the options. Suppose a small economic cost, FL, yields the full social gain, DG, (e.g. by targeting poor households), while a large cost, LI, is required to realise the environmental benefit, EH, (e.g. better water supply and sanitation). Here, the social gain may be more cost effective than the environmental benefit, especially if purely budgetary constraints limit cost increases to less than FK.

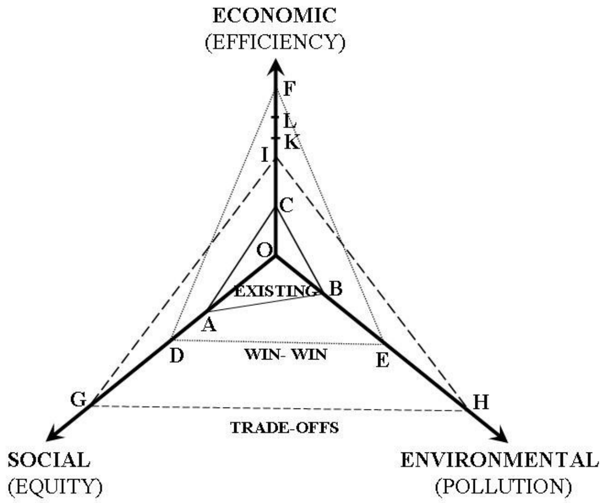


Figure 4. Multi-criteria analysis applied to sustainable water management and planning.
Source: Adapted from Munasinghe (2007)

## Concluding remarks

Water scarcity, climate change and sustainable development are interlinked problems that pose serious risks to humanity. Short-sighted and piecemeal policies have not proved effective so far. The paper outlines how a longer-term vision of sustainable development needs to go below surface level indicators of development, by addressing deeper issues systematically and focusing on both immediate drivers and underlying pressures.

It is possible to conclude on a mildly optimistic note. Although the issues are complex and serious, multiple problems could be solved together, provided we begin immediately. We know enough already to take the first steps that will transform the risky "business-as-usual" scenario into a safer future. The sustainomics framework for making development more sustainable is an effective method that integrates solutions to these multiple challenges into a coherent sustainable development strategy. The approach relies on a balanced and integrated analysis from three main perspectives – social, economic and environmental. Civil society and business must play a bigger role in helping governments find and implement solutions. A number of case studies at the global, national and local levels illustrate practical applications of the methodology. ■

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