Strengthening Climate Resilience

Greening disaster risk management:

Issues at the interface of disaster risk management and low carbon development

Frauke Urban, Tom Mitchell and Paula Silva Villanueva

Strengthening Climate Resilience Discussion Paper 3

Strengthening Climate Resilience (SCR) – through Climate Smart Disaster Risk Management' is a UK Department for International Development funded programme that aims to enhance the ability of developing country governments and civil society organisations to build the resilience of communities to disasters and climate change. It is co-ordinated by the Institute of Development Studies (UK), Plan International and Christian Aid, who are working with a variety of organisations across ten countries (Kenya, Tanzania and Sudan in East Africa; Nepal, India, Bangladesh and Sri Lanka in South Asia and Philippines, Indonesia and Cambodia in South East Asia). SCR has developed the Climate Smart Disaster Risk Management Approach (see Climate Smart Disaster Risk Management). If you would like to be involved in SCR meetings or work with the programme to trial the Climate Smart Disaster Risk Management Approach with your organisation, please either visit the SCR website: www.csdrm.org or send an e-mail to info@csdrm.org

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Available from:
Strengthening Climate Resilience
Institute of Development Studies
at the University of Sussex
Brighton BN1 9RE, UK
T: +44 (0)1273 606261
info@csdrm.org
www.csdrm.org

Frauke Urban is a Research Fellow at the Institute of Development Studies

Tom Mitchell, Overseas Development Institute, was Director of the Strenghthening Climate Resilience programme at the Institute of Development Studies from October 2009- August 2010

Paula Silva Villanueva is affiliated with the Institute of Development Studies.

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Abstract

Effectively managing disaster risk is a critical tool for adapting to the impacts of climate change. However, consideration of climate change mitigation and low carbon development aspects have commonly been missing from disaster risk management (DRM) research, policy and practice.

This paper explores the links between DRM and low carbon development and thereby sheds light on a new and emerging research and development agenda. It elaborates the carbon and greenhouse gas implications of DRM interventions and post-disaster reconstruction practices, drawing on case studies from flood risk reduction, coastal protection and drought risk reduction and considers how post-disaster housing and energy supply reconstruction can be 'greened'.

Finally, the paper makes suggestions about how the carbon implications of DRM measures could be accounted for in a coherent manner. Suggestions include calculating the carbon and other greenhouse gas emissions from DRM and post-disasters interventions as parts of Environmental Impact Assessments and improving the linkages between environmental ministries, energy ministries and disasters ministries.

1. Introduction: the interplay between climate change, mitigation and disasters

Global climate change is considered one of the greatest threats to development efforts. It poses risks to humans, the environment and the economy. The Intergovernmental Panel on Climate Change (IPCC) reports that the global mean surface temperature has risen by 0.74°C ± 0.18°C during the last century. This increase has been particularly significant over the last 50 years (IPCC 2007). Global climate change has adverse effects on agriculture, water, food production, human and animal health, coastal areas, energy and many other sectors. Climate change can exacerbate existing disaster risks and increases the frequency and severity of some extreme climate events, such as heatwaves and heavy precipitation events (IPCC 2007). There is thus a direct link between climate change and disasters.

To tackle climate change, both adaptation to climate change and mitigation of greenhouse gas emissions are important. Climate change mitigation[1] is defined by the IPCC as 'an anthropogenic intervention to reduce the anthropogenic forcing of the climate system; it includes strategies to reduce greenhouse gas sources and emissions and enhancing greenhouse gas sinks' (IPCC 2007: 379). While the scientific community, practitioners and policymakers have focused on climate change mitigation for a long time, the focus has recently shifted to low carbon development (LCD). Low carbon development is defined by the UK's Department for International Development (DFID) as (1) using less energy and improving energy; (2) protecting and promoting carbon sinks; (3) promoting low or zero-carbon technologies and business models; (4) introducing policies which discourage carbon-intensive practices (DFID 2009 :58). Low carbon development aims for climate-friendly economic and social development, which is important, both for developed and developing countries. In high-income countries and emerging economies LCD is mainly about reducing emissions, while in low-income countries LCD is mainly about the opportunities and benefits it can offer, such as access to electricity from renewable energy, green jobs, payments for sustainable forest management and distributive effects (Urban 2010).

The disaster risk management (DRM) community has been actively engaged in issues related to climate change adaptation (Mitchell et al. 2010). DRM is seen as a critical tool for adapting to the impacts of climate change where tackling the adaptation deficit (Burton 2004) to existing climate variability is viewed as a sensible first step. Despite the fact that disaster risk management, climate change mitigation and adaptation share common goals, namely reducing the vulnerability of communities and achieving sustainable development, mitigation issues and low carbon development issues have not been systematically addressed by the DRM community so far. This is a trend that can be observed in other development sectors and programmes as well, where climate change adaptation tends to play a dominant role while mitigation aspects receive less attention. One could therefore argue for the need for 'greening' development efforts at a wider scale. However this type of general assessment is too broad for one paper and we therefore focus on 'greening' DRM in this paper.

This paper aims to explore the links between disaster risk management and low carbon development and thereby shed some light on a new and emerging research and development agenda. The most important links between DRM and low carbon development are related to three issues: (1) the carbon and greenhouse gas implications of measures to reduce disaster risk; (2) the carbon and greenhouse gas implications of post-disaster and reconstruction interventions; (3) changing disaster risk for low carbon development options and their limits.

We will elaborate on the first two links between DRM and LCD, while the third link needs further elaboration in the future, but goes beyond the scope of this paper. Both DRM interventions and reconstruction interventions can either contribute to greenhouse gas emissions and therewith climate change or mitigate the emission of greenhouse gas emissions, for example by sequestering carbon. Section 2 explores the low carbon development implications of DRM interventions, section 3 explores the implications for

[1] We use the term 'mitigation' in this paper in relation to climate change mitigation, not in relation to disaster mitigation.

reconstruction interventions and section 4 discusses and concludes the paper. This paper brings an original approach to both the disasters and low carbon research themes as it aims to explore issues at the interface of both themes and elaborate the policy and practice implications.

2. Disaster risk management interventions and implications for low carbon development

2.1 Environmental considerations of disaster risk management interventions

Considerable research and analysis has been undertaken by the United Nations International Strategy for Disaster Reduction (UNISDR) to illuminate the connections between environmental hazards, sustainable development strategies and disaster response and management. Living with Risk (2004), produced by the UNISDR, puts it most succinctly:

> The environment and disasters are inherently linked. Environmental degradation affects natural processes, alters humanity's resource base and increases vulnerability. It exacerbates the impact of natural hazards, lessens overall resilience and challenges traditional coping strategies. Furthermore, effective and economical solutions to reduce risk can be overlooked... Although the links between disaster reduction and environmental management are recognized, little research and policy work has been undertaken on the subject. The concept of using environmental tools for disaster reduction has not yet been widely applied by practitioners (UNISDR 2004: 195).

The Hyogo Framework of Action (UNISDR 2005a) argues that 'reducing the underlying risk factors' related to the environment and disasters is a priority for action. The framework specifically recommends environmental and natural resource management and other efforts that:

- encourage the sustainable use and management of ecosystems, including through better land use planning and development activities to reduce risk and vulnerabilities;
- implement integrated environmental and natural resource management approaches that incorporate disaster risk management, including structural and non-structural measures, such as integrated flood management and appropriate management of fragile ecosystems.

Environmental management and practices have started to be applied within organisations' DRM guidelines (e.g. see Tearfund 2009). However, issues related to carbon emissions or other greenhouse gas emissions have received very little consideration so far and are not commonly considered in environmental impact assessments of DRM interventions. Measures to reduce disaster risk include hard structural interventions, such as levees, sea walls, earthquake-resistant buildings and evacuation shelters (UNISDR 2005a) – these are all physical constructions that use building materials and energy resources that have carbon and other greenhouse gas emissions implications.

Taking carbon considerations into account in risk reduction, relief and reconstruction would contribute to the potential 'greening' of the DRM industry. This is an important dimension for recognising the benefits that a low carbon economy can bring to developing countries and the overall problem being created by emitting more greenhouse gases, rather than an effort to reduce the emissions of countries that are disaster-prone and already have very low emissions. Therefore efforts to support a low carbon DRM industry that takes its carbon implications into account should not be an attempt to reduce emissions in poor countries, but should be about raising awareness of the potential climate-related damage being caused by DRM interventions and encouraging the choice of climate-friendly alternatives where appropriate. Urban (2010) stresses that measures for low carbon development in poor countries are mainly about the benefits and opportunities they can bring, rather than about cutting emissions.

2.2 Greenhouse gas and carbon emission implications of disaster risk management interventions

There are strong arguments to support the idea that disaster risk management interventions should aim to reduce greenhouse gas emissions to avoid further contribution to the risks posed by climate change (Curtis 2009). While development and DRM agencies are increasingly aiming to reduce organisational carbon footprints, it is time to start thinking about intervention-level carbon impacts. Bockel reports that, for example, the World Bank supports the piloting and development of a mix of market and non-market mechanisms to encourage agricultural carbon sequestration and reduce carbon emissions for development projects (Bockel et al. 2010). Among others, it is piloting a range of approaches to estimating the carbon footprint of its projects and DRM interventions. These include (1) listing activities which contribute to mitigation or adaptation; (2) testing and rolling out more robust estimation tools for measuring carbon footprints; (3) project-based carbon measurement for access to the voluntary carbon market; (4) sharing knowledge between and within countries (Fernandes and Thapa 2009).

Accordingly, this section will elaborate the carbon emission implications of selected examples of three important types of DRM interventions: flood risk management interventions, coastal protection and drought risk management.

2.2.1 Flood risk management: hydropower dams and reservoirs

Engineered structures such as hydropower dams are a common intervention to reduce risks from floods. The efficacy of these structures is sometimes questioned as they can result in negative consequences downstream and their environmental impacts can be high, for example by directly or indirectly affecting coastal or riparian environments, fisheries and natural processes of erosion and sedimentation. Despite these negative impacts, construction-based flood risk reduction efforts, such as dams and hydropower reservoirs, are a significant component of disaster prevention (UNEP 2007). Many dams were originally built for power generation and water storage irrigation, but more recently dams have been built especially for flood control (Schultz 2002; World Commission on Dams 2000a). Dams allow the retention of runoff which can be released in dry periods. 'The dams closest to the origins of the tributaries restrain the floodwaters while the dams further downstream release their reserves and the flood waters are then released into each succeeding dam and finally into the main river' (McCartney et al. 2001: 1).

Dams have long been recognised for (1) providing 'green' electricity without the level of greenhouse gas emissions and pollution that are often linked to other energy sources; (2) flood protection; and (3) making water available for agriculture and human needs. Since the 1990s, a controversial debate has raged about large dams and about 'conflict over how to develop these water and energy resources'. As a response, the World Commission on Dams (WCD) was created in 1997 and represents a diverse group of 'engineers, planners, dam owners, government decision-makers, environmental scientists, affected peoples and indigenous peoples, academics and researchers' (WCD 2000b: 1).

Recently there has been an ongoing debate about greenhouse gas emissions (GHG) from large dams and reservoirs. There are GHG emissions from several different sources:

- GHG emissions due to the industrial production of the dams, mainly from the production of concrete, steel and power lines for connection with the nearest grid (e.g. Rashad and Ismail 2000). Life cycle analysis shows that the GHG emissions from both large and small hydropower schemes are similar to those of other renewable energy plants and are significantly below those of fossil fuel plants (Gagnon et al. 2002; Evan et al. 2008).
- Emissions from bacterial decomposition of organic material underwater after flooding of the vegetation (Rosa et al. 2004). The gases emitted are mainly nitrous oxide carbon dioxide and methane. There is uncertainty about whether methane emissions depend on the age of the dams (Fearnside 2002; Rashad and Ismail 2000; Ruiz-Suarez et al. 2003; Rosa et al. 2004). The carbon content in tropical ecosystems is higher than that of boreal and grassland ecosystems, so that more GHG emissions are emitted from tropical dams (Rashad and Ismail 2000).
- Emissions from above-water decay: aerobic decay of biomass which has not been completely flooded, leaving parts above water (Fearnside 2002). However, there is some degree of scientific uncertainty and ambiguity about this source of emissions.

The International Hydropower Association reports that GHG emissions occur naturally from many wetland ecosystems, such as bogs, marshes, swamps, floodplains and lakes (IHA 2005). The GHG emissions from reservoirs are reported as being similar to those from other wetland ecosystems. The IHA further reports that measuring the emissions from the surface of the reservoirs might be misleading. Instead, net emissions should be calculated which should consider the emissions from ecosystems before the creation of the reservoir. 'To define "net" emissions, it is essential to look at the different ecosystems that are replaced by freshwater reservoirs' (IHA 2005). However, one has to be cautious with regard to the approach mentioned by the IHA, as it comes essentially from an interest group promoting hydropower. The discussion and scientific evidence about GHG emissions from hydropower dams is inherently complex; this paper aims to highlight this complexity and the associated scientific uncertainty.

Many studies seem to agree that GHG emissions from dams range in average between 40–45g CO2 equivalents/kWh, with smaller dams and dams in cooler climates being at the lower end of the scale and large dams and dams in the tropics being at the upper end of the scale (Rashad and Ismail 2000; Gagnon et al. 2001; International Rivers Network 2002; IHA 2005; Evans et al. 2008). It seems to be a widely accepted fact that there are GHG emissions from hydropower plants. Most studies agree, however, that hydropower dams produce lower GHG emissions during their lifetime than fossil fuel plants, namely at least 10 times lower (Gagnon et al. 2001; World Commission on Dams 2001; IHA 2005).
The high social implications of large dam building should also not be neglected. These often involve resettlement, loss of livelihoods, inadequate or no compensation payments and other negative effects. Small hydropower plants, and particularly micro- and pico-hydropower plants, usually have very little impact on GHG emissions, because they are mainly from river runoff and often do not include any dams or reservoirs.

Debates around low-impact and non-structural alternatives to dams that reduce flood risk while being environmentally friendly have started to emerge. For example, the Government of Japan is shifting its flood protection interventions based on concrete river walls to construction based on ecosystem restoration (UNEP 2007). Similar approaches are reported in Central Europe such as along the river Danube. In recent years attention has been paid to using environmentally friendly alternatives to large structural flood management. This new approach calls for integrated management of the watershed, river, and floodplain, and incorporates non-structural strategies in addition to other traditional flood management structures (Brink et al. 2004). Maintaining watersheds by avoiding deforestation and diversion of waterways protects water quality and quantity, as well as preserving livelihoods dependent on fisheries. Risk management measures, such as appropriate construction to withstand storm and flood, can also help communities in adapting to climate change (UNISDR 2007).

2.2.2 Coastal protection
Coastal areas are particularly prone to disasters such as storm surges and sea-level rises. Coastal protection depends both on structural DRM interventions such as sea walls and dams and on non-structural interventions such as land use management/ecosystem-based risk management. Ideally an appropriate mix of the two approaches is used for coastal protection. An example is Sri Lanka, where the Disaster Management Centre has studied the potential benefits of adopting hybrid schemes or 'soft engineering' approaches to coastal defence (UNEP 2007).

There is an increasing recognition that effective reduction of coastal disasters is possible through healthy coastal forests, in particular mangrove forests (Mazda et al. 2004; Othman 1994; UNISDR 2005b). Mangroves are important sources of income for securing the livelihoods of local fishermen who depend on them due to their abundance of fish, shrimps and other aquatic organisms. However, for decades these natural barriers have been in decline in many places due to adverse environmental conditions and human activities such as cutting the mangroves down for fuel wood or for agriculture. Osti et al. (2008) report that in the past 20 years, 50 per cent of the world's mangrove forests have been lost; making them one of the world's most endangered landscapes. Some argue that this reduction in mangrove forests is to some extent associated with the significant economic interests in commercial shrimp farming. It is essential to recover these forests and to use them as a shield against costal disasters and as a resource to secure optimal socioeconomic, ecological and environmental benefits. UNEP reports how mangroves in Vietnam have contributed to disaster risk management:

> Vietnam is one of the most typhoon-struck countries in Asia... [The] Red River delta – an

> extensive rice-growing area in northern Vietnam [is] one of the most densely populated regions in the world. The mudflats of the delta were claimed for agriculture over several centuries by building dykes. Local communities traditionally left a band of natural saltwater- tolerant mangrove forest between the dykes and the sea in order to help protect the rice fields from waves, wind and typhoon damage. However, the cutting of the mangrove forests for fuel and the spraying of chemical defoliants during the war in the 1970s destroyed most of this natural protection belt. As a result, some of the dykes started to erode, posing an increasing risk to people and their rice fields… The Vietnamese Red Cross planted more than 175 km2 of mangrove forest along almost 200 km of coastline, representing nearly the entire coastline (where natural conditions allowed). Local communities carried out the planting and were granted the right to harvest marine products such as crabs and mussels in the areas they had planted for a number of years... The planting and protection of 12,000 ha of mangroves cost around USD 1.1 million, but helped reduce the cost of dyke maintenance by USD 7.3 million a year. The Red Cross also estimates that 7,750 families improved their livelihoods, and hence their resilience to further hazards, through the selling of crabs, shrimps and molluscs. (UNEP 2007: 25)

It is reported that coastal wetlands can potentially accumulate carbon at high rates over long periods of time. Mangroves play an important role: Chmura et al. (2003 cited in Trumper et al. 2009) calculated that mangrove accumulates around 0.038 gigatonnes carbon (GtC) per year globally. Suratman (2008) argues that, taking area of coverage into account, mangroves sequester carbon faster than terrestrial forests (Suratman 2008). Trumper et al. (2009) report that, globally, tropical and subtropical forests such as in mangrove-growing regions store 547.8 GtC within the entire biome.

Improved ecosystem management represents a valuable approach for both disaster risk management and climate change mitigation. Protected and well-managed ecosystems are a cost-effective approach to promoting sustainable livelihoods and effective coastal protection with increased resilience[2] . They also have the added benefits of low carbon development. Some sources suggest that improved ecosystem management can offer new economic opportunities through global carbon trading schemes (Sudmeier-Rieux and Ash 2009; UNEP and UNISDR 2008). This would be the case where specific activities qualify under carbon trading standards or projects qualify under the REDD (Reducing Emissions from Deforestation and Forest Degradation) and LULUCF mechanisms (Land Use and Land Use Change and Forestry).

REDD

> is an effort to create a financial value for the carbon stored in forests, offering incentives for developing countries to reduce emissions from forested lands and invest in low-carbon paths to sustainable development. 'REDD+' goes beyond deforestation and forest degradation, and includes the role of conservation, sustainable management of forests and enhancement of forest carbon stocks (UN-REDD Programme 2010).

The UNFCCC (2010: 1) mentions that

> activities in the LULUCF sector can provide a relatively cost-effective way of offsetting emissions, either by increasing the removals of greenhouse gases from the atmosphere (e.g. by planting trees or managing forests), or by reducing emissions (e.g. by curbing deforestation).

These activities include afforestation, reforestation, forest management, cropland management, grazing land management and revegetation

2.2.3 Drought risk management

Agriculture, and especially food production, is one of the most climate-sensitive sectors. Communities heavily dependent on agriculture are increasingly vulnerable to disasters due to losses of harvests, destroyed plantations, salinisation, animal losses and disease, etc. On the other hand, it is reported that agriculture currently contributes to about 30 per cent of global GHG emissions, but has a major potential to serve both as mitigation and adaptation option for tackling climate change and reducing poverty (Fernandes and Thapa 2009).

[2]The term 'resilience' is increasingly used in climate change and disaster discourses and in policies and programming related to these issues. It has become common to describe the intersection between these two fields and those of poverty and development as 'climate resilient development'. The SCR programme recognises the difficulty in operationalising the concept of resilience and its multiple meanings and as such has chosen to focus on more tangible and practical dimensions of 'adaptive capacity'. Carpenter et al. highlight that little attention has been paid to the operational indicators of resilience (2001). For more details on resilience see Bahadur et al. 2010.

In terms of irrigation, low carbon energy technologies can offer benefits: case studies from India and Brazil, for example, show how solar panels and small wind turbines can power irrigation pumps for increased agricultural productivity and for reducing drought risks. This is just one example of how irrigation, drought risk management and low carbon development are linked (Wisions 2007).

UNISDR (2007) reports the following case study from Kenya which shows how the planting of trees can reduce drought risk while sequestering carbon and mitigating climate change:

> The Green Belt Movement (GBM) of Kenya… fosters local-based efforts to create a more sustainable environment that will be more resilient to the effects of drought. The program creates a culture of resilience by encouraging women and men in rural areas to plant and nurture native trees. Established in the mid-1970s, GBM is credited with planting more than 30 million trees and is now expanding to other African countries. Its founder, Wangari Maathai, won the Nobel Peace Prize in 2004. (UNISDR 2007: 45)

The movement was set up to decrease negative effects from deforestation and agricultural intensification which led to erosion, lower fertility of soils, reduced water availability, a reduction in wildlife, shade and air quality.

> The result was greater vulnerability to drought, malnourishment, famine, and death. Maathai taught women to collect seeds of indigenous trees from their immediate surroundings and to nurture them using whatever resources were at hand. GBM paid the women a token amount for each seedling that survived… GBM organizers conducted a variety of environmental education and awareness activities for its 'foresters without diplomas', and made a point to listen to people in their native languages as they shared traditional knowledge from their particular areas. (UNISDR 2007: 45)

This example demonstrates how one programme aimed at planting trees has grown to meet the broader needs of local communities, such as increasing reforestation, increasing food security, empowering women, and providing for environmental education and leadership capacity development. The programme reduces the risks of climate-related disasters such as drought and famine while it contributes to carbon uptake from the atmosphere. For example, Trumper et al. (2009) report that, globally, grasslands, savannah and shrublands such as in Kenya and large parts of sub-Saharan Africa store 285.3 GtC within the entire biome. However, the green belt movement, and similar tree-planting efforts, are not without problems, and have been critiqued for their very simplistic assumption that tree planting is a solution, without considering people's livelihoods and the feasibility of tree planting in the local areas.

3. Post-disaster and reconstruction interventions and the implications for low carbon development

Section 2 elaborated the carbon and greenhouse gas implications of DRM interventions with specific examples for flood risk management, coastal protection and drought risk management. This section examines the carbon and greenhouse gas implications of post-disaster relief and reconstruction interventions. This section draws particularly on case studies from housing reconstruction interventions and post-disaster energy supply.

3.1 Environmental considerations of post-disaster and reconstruction interventions

In 1997, in recognition of concerns about humanitarian response efforts, non-governmental organisations (NGOs) launched the Sphere Project[3], the first collaborative initiative to produce globally applicable minimum standards for humanitarian response. The aims of the Sphere Project are to improve the effectiveness of humanitarian efforts and to enhance the accountability of the humanitarian system, primarily to those people who need protection and assistance in disasters, as well as to agency members and donors (The Sphere Project 2004). Besides humanitarian response efforts, reconstruction efforts after disasters are crucial. Among others, the Sphere standards emphasise the need for stressing the critical role of ensuring future disaster risks are not overlooked in the rush to restore the situation in disaster regions to pre-disaster conditions.

Post-disaster situations create enormous pressure to provide survivors with adequate permanent housing and other vital supplies as rapidly as possible. The urgent need for housing normally leads to large-scale reconstruction programmes and huge demand for construction material. Moreover, in post-disaster situations, environmental assessments are often neglected in order to speed up reconstruction (UNEP and SKAT 2007).
The pressure to regain equilibrium as quickly as possible must be balanced against seizing opportunities for long-term risk reduction, adaptation to climate change and community improvements through sustainable reconstruction.

After the 2004 Indian Ocean tsunami, the DRM community embraced the principle of "Build Back Better". The aim was to assess existing problems and development issues and take them into account in further actions in order to improve the lives of both the people affected and future generations (Chang et al. 2010; Kennedy et al. 2008).

The 2010 post-disaster reconstruction guidelines, Lessons from Aceh, produced by Disasters Emergency Committee (DEC) members, highlights the importance of Environmental Impact Assessments (EIAs) in reconstruction programmes and the opportunities that post-disaster reconstruction processes may bring for introducing low carbon technologies (Da Silva 2010). The guidelines propose including the following key questions in EIAs to better link disasters, environmental effects and low carbon issues:

- How did the disaster affect the environment? How can reconstruction protect, repair and enhance ecosytems?
- Is there potential to re-use or recycle waste materials generated by the disaster? Can transitional shelters be re-used or incorporated into permanent housing?
- What materials are available locally and are they sustainably sourced and certified? Is there potential to introduce new materials or manufacturing processes which have less environmental impact?
- How are building components manufactured? Do they require energy intensive processes or create toxic waste products?
- What is the source of potable water? Has this been affected by the disaster? How can sanitation and solid waste management be designed to protect and enhance water sources?
- Is there potential to incorporate rainwater harvesting, renewable energy, composting or biogas toilets? Are these appropriate and would they be maintained?

(Da Silva 2010: 21)

Unfortunately, these EIA considerations for Aceh do not include assessments of carbon

[3]The Sphere Project, www.sphereproject.org/content/view/443/264/lang,english/, accessed 31 May 2010.

dioxide and other greenhouse gas emissions of reconstruction interventions. The problem is that there are no globally agreed standards for EIA. Instead, these often differ in various regions of the world. The EU has developed its own guidelines for EIAs as the following example highlights:

> Environmental impact assessment (EIA) is an important procedure for ensuring that the likely effects of new development on the environment are fully understood and taken into account before the development is allowed to go ahead.

(UK Department for Communities and Local Government [DCLG] 2000: 5)

The following developments need EIA:

i. major developments which are of more than local importance;
ii. developments which are proposed for particularly environmentally sensitive or vulnerable locations;
iii. developments with unusually complex and potentially hazardous environmental effects.

(DCLG 2000: 9)

The agreed EIA procedures in the EU require: information on 'emissions to air' from production processes of the proposed development; a description of climatic factors and air quality (DCLG 2000: 56); assessments of effects from 'emissions from the development during normal operation' (DCLG 2000: 57); and an elaboration of mitigation measures to reduce environmentally adverse effects, which is however not specifically related to reducing emissions (DCLG 2000: 58 9). The EU's EIA guidelines take into account carbon and greenhouse gas emissions; however, other countries often have less strict regulations. It is often suggested that EIAs have either been ignored to some extent or even omitted altogether, particularly in relation to large hydropower developments in the developing world. An example is the large-scale development of hydropower dams along the Mekong River, particularly in Lao and Cambodia (Mekong River Commission 2007; Polack 2010).

3.2 Greenhouse gas and carbon emission implications of post-disaster relief and reconstruction interventions

The following two sections will highlight case studies from housing reconstruction and post-disaster energy supply and their GHG implications.

3.2.1 Housing reconstruction

The exploitation of natural resources during post-disaster situations for intensive production of building materials may sometimes cause irreversible environmental impacts and degradation (Roseberry 2008; Chang et al. 2010), followed by high levels of carbon emissions (O'Brien et al. 2008). For example, timber products are common building materials which are often used for post-disaster reconstruction interventions. Unsustainable timber harvesting can lead to a decline in forest size and quality and reduce natural carbon uptake.
Forests and wood are integrally linked to climate change and have an important role to play in mitigation and adaptation (Van Bodegom et al. 2009). Forests sequester carbon from the atmosphere when they grow, thereby significantly offsetting GHG emissions. Forests store more than 80 per cent of terrestrial above-ground carbon and more than 70 per cent of soil organic carbon (Van Bodegom et al. 2009; Prins et al. 2009). They are also a source of fuel and modern biomass (such as wood chips) that can substitute for fossil energy, thereby reducing GHG emissions.

There is an increasing understanding of the relationship between house type and environmental sustainability which is being considered for reconstruction interventions (O'Brien et al. 2008; Chang et al. 2010). The following case study indicates how different types of post-tsunami reconstructions in Indonesia had direct carbon and GHG implications. O'Brien et al. (2008) report that after the Indian Ocean Tsunami in 2004, housing reconstruction agencies aimed to build houses based on mass-produced construction materials.

> The dominant house type built by reconstruction agencies followed the ubiquitous 'bungalow' model and was constructed with industrialized materials. Other types were

> hybrid models that used the industrialized materials but traditional 'house on stilts' typologies. In Aceh, Indonesia, the adoption of these types extended existing trends away from vernacular traditions and materials such as timber and bamboo. (O'Brien et al. 2008: 361)

Researchers examined the sustainability of three house types built by reconstruction agencies in Aceh and compared these with the traditional style of timber house. The study used Life Cycle Assessment (LCA) to determine the sustainability of each type of house, calculating both the CO2 emissions and the ecological footprint of each house. 'The ecological footprint shows how much biologically productive land and water a house requires throughout its life-cycle' (ibid.: 363). LCA is a method for assessing the environmental impacts of specific products or processes during their life cycle, taking into account the production, use, transport and recycling phases. The study found that the post-tsunami reconstruction housing types were:

> linked with levels of greenhouse gas emissions up to fifty times higher than traditional types and triple the ecological footprint of traditional types. This increase is primarily due to the overwhelming use of externally procured and imported construction technologies and mass-produced materials. (ibid.: 361)

The study confirmed that, based both on CO2 emissions and on ecological footprints, traditional housing types constructed with locally harvested timber are the key to reducing negative environmental impacts associated with post-disaster housing (O'Brien et al. 2008).

3.2.2 Post-disaster energy supply

Post-disaster reconstruction provides an opportunity to address the need for household energy supply. Energy is a vital commodity and is closely intertwined with climate change and development. Energy is a basic human need for cooking, heating, lighting, boiling water and for other household activities. Energy is also required to sustain and expand economic processes like agriculture, electricity production, industries, services and transport. It is commonly suggested that access to energy is closely linked with development and economic growth (e.g. DFID 2002; IEA 2002; WEC 2000; WEC 2001; WHO 2006) and that alleviating energy poverty is a prerequisite to fulfilling the Millennium Development Goals (DFID 2002; WHO 2006).

In 2007, about 80 per cent of the global energy supply came from fossil fuels such as coal, oil and natural gas (IEA 2010). Fossil energy resources are finite and fossil energy use is associated with a number of negative environmental effects such as climate change, resource depletion and air pollution. Fossil fuels may also create a dependency on resources that are not locally available but need to be imported. These energy choices are therefore more expensive and inconvenient for poor households (UN Habitat 2007) and they pose a threat to energy security. Extensive fossil fuel use ultimately leads to a 'carbon lock-in', with infrastructure and investments bound to a carbon-intensive economy for decades. Relying on them can mean greater costs in the long run (Urban and Sumner 2009).

Most developing countries rely primarily on traditional biofuels such as wood as primary energy sources (Karekezi et al. 2004; Urban and Sumner 2009). The use of traditional biofuels is considered to have high health impacts. They are associated with pneumonia, chronic respiratory disease, lung cancer and adverse pregnancy outcomes due to exposure to indoor air pollution and body deformations as a result of collecting wood for fuel (WHO 2000; WHO 2005; WHO 2006). The World Health Organization (WHO) reports that 4.7 per cent of all deaths in the least developed countries could be due to traditional solid fuel use (WHO 2000). According to WHO (2005), 1.6 million people mainly women and children are likely to die every year, because of exposure to indoor air pollution from traditional biofuels. Replacing traditional biofuels with modern renewable energy sources is likely to increase the health of the population in developing countries. Renewable energy can also reduce GHG emissions, reduce dependence on energy imports and increase energy security. At the same time, renewable energy technology such as solar panels, lamps and cookers, small wind turbines, small hydropower and biogas cookers, can be used for lighting, cooking, heating and other household activities. The social and environmental benefits of improved cooking stoves have been widely assessed (DFID 2002). Co-benefits include access to energy for poor households, health benefits, increased income opportunities, positive effects on education (such as being able to study after dark and having electricity and heating in schools), reduced workloads from wood collection, safety benefits and a number of environmental advantages such as reduced pressure on finite energy resources and forests and improved air quality. Renewable energy can be an option for providing off-grid decentralised energy. This is particularly important in rural areas and for post-disaster reconstruction when the central grid does not exist or has been damaged.

It has been reported that renewable energy is used in many post-disaster and reconstruction interventions. One example is from Haiti where, after the 2010 earthquake, solar energy is used to power healthcare services and reconstruct the damaged power infrastructure (Renewable Energy World 2010; Inhabitat 2010). This is carbon-neutral and offers a quick and cost-effective way of rebuilding the power supply in a sustainable low carbon way. Other examples have been reported from Sichuan province where, after the earthquake in 2008, DFID China gave US$1 million for technical assistance and 20 per cent of the funding is being used to reconstruct the city of Guangan as a low carbon city. This low carbon reconstruction focuses on three main areas: promoting renewable energy such as solar and wind energy, building a low carbon community and promoting low carbon lifestyles and creating low carbon buildings (Wang 2010).

3.3 Practical implications

The task of reconstruction after a major disaster can be a difficult challenge and the introduction of low carbon materials and technology may not facilitate the task in the short-term. It will require deliberate and coordinated efforts of all stakeholders for effective recovery that provides new paths to low carbon development.

The responsibility for establishing and implementing reconstruction policies rests primarily with governments. Most countries have their own institutional arrangements for disaster management, including reconstruction. Post-disaster responses by national governments, bilateral aid agencies, NGOs and UN agencies have been characterised by rapid rehabilitation projects including water and sanitation, housing, irrigation, food security and health. These are often ad hoc and separate from the overall development objectives of disaster-hit countries. The real challenge lies in broadening the remit of humanitarian, developmental and environmental bodies and in bringing them together in a shared effort for achieving sustainable recovery (UN Habitat 2007).

Disaster risk reduction, relief and reconstruction need to be seen as opportunities for developing countries to reap multiple benefits in terms of development and resource management that can also help to mitigate GHG emissions at the same time.
This section has elaborated the challenges to and opportunities for incorporating carbon emission implications in post-disaster circumstances. Challenges are posed, for example, by time constraints, while opportunities include the additional benefits of off-grid renewable energy. Low carbon development can be stimulated in post-disaster circumstances by (1) fostering the use of low-hanging fruit technologies (such as renewable off-grid electricity supply); (2) planning ahead, not just by having risk maps and disaster-resilient building codes ready for when a disaster strikes and rapid reconstruction is needed, but also factoring in low carbon development considerations at a much earlier phase.

4. Discussion and conclusions

Incorporating carbon emission considerations in disaster risk management approaches can increase the opportunities that low carbon development can bring. In line with this thinking, this paper elaborates issues at the interface of disaster risk management and low carbon development. The paper explores the importance of greening disaster risk management, because this and post-disaster reconstruction interventions can either create greenhouse gas emissions or mitigate them.

From analysing current literature in this field it is clear that the carbon and greenhouse gas implications of disaster risk management and post-disaster interventions – and development efforts in general remain a major gap in research and practice so far. Further exploration is required of the carbon emission implications of disaster risk management practices and options for reducing their impacts. Further research is required into the potential for low carbon options such as sustainably sourced building materials, renewable energy options and natural protection against disasters options which can sequester carbon and thereby mitigate climate change.

This paper has illustrated that there is scope for DRM and reconstruction interventions to respond both to climate change adaptation and mitigation. Taking a strategic approach to risk management before and after disaster situations can potentially lead to a triple benefit effect, namely reducing disaster risk, enhancing adaptation and mitigation.
Mitigation actions may include renewable energy systems, carbon sequestration by forests and wetlands and improved land use planning. Minimising negative impacts on natural carbon sinks, such as forests, vegetation and soils, that absorb carbon dioxide, has been identified as a win-win option for DRM interventions. Including low carbon renewable energy technology and greening initiatives in the planning and execution of DRM intervention can substantially reduce emissions and other potentially negative environmental impacts.

The following suggestions could promote more coherent consideration of the carbon emission implications of DRM measures:

- CO2 and other greenhouse gas emissions from DRM interventions should be calculated and their risks assessed as part of Environmental Impact Assessments. To some extent this is included in EU's EIAs but this practice is underused in many developing countries. An international standardisation of EIAs could offer a comprehensive, harmonised approach. This could reduce a number of adverse environmental effects including those related to emissions leading to climate change in developing countries as well as in developed countries;
- Life Cycle Assessments of structural interventions such as sea walls, dykes and large hydropower dams should be conducted and should be made publically available to increase the information available for future interventions and enable improved decision-making;
- Improve the linkages between environmental ministries, energy ministries and disasters ministries on low carbon development and mitigation issues;
- Sphere standards to include measures to address the emissions of relief operations;
- Reconstruction processes to include analysis of low carbon scenarios.

So far, data for the above suggestions are in short supply. For example, there is very little information about life cycle assessments relevant to DRM interventions; however, this could become more prominent in the future. Ideally, DRM and post-disaster intervention teams should work with mitigation specialists for advice and calculations on carbon footprint, mitigation potentials, low carbon reconstruction processes and renewable energy options. An improved cooperation between national and local authorities involved in disaster planning and low carbon development planning, along with improved cooperation of disaster and low carbon specialists, could contribute to the greening of disaster relief and reconstruction practice and policy and lead towards a low carbon pathway in the long run.

Finally, many useful low carbon development practices can at the same time be useful DRM practices. These low carbon practices should be favoured while high carbon practices should be avoided. For high-income countries and emerging economies there should be increasing efforts to reduce emissions within their DRM and reconstruction efforts. For low-income countries, this is mostly about the benefits low carbon development can bring, such as access to low carbon energy, rather than about full optimisation of all DRM and reconstruction efforts.

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The Climate Smart Disaster Risk Management Approach

Strengthening Climate Resilience

The questions in the approach are suggestions only and there may well be others

1. Tackle changing disaster risks and uncertainties

1a

Strengthen collaboration and integration between diverse stakeholders working on disasters, climate and development

To what extent are climate change adaptation, disaster risk management and development integrated across sectors and scales? How are organisations working on disasters, climate change and development collaborating?

1b

Periodically assess the effects of climate change on current and future disaster risks and uncertainties

How is knowledge from meteorology, climatology, social science, and communities about hazards, vulnerabilities and uncertainties being collected, integrated and used at different scales?

1c

Integrate knowledge of changing risks and uncertainties into planning, policy and programme design to reduce the vulnerability and exposure of people's lives and livelihoods

How is knowledge about changing disaster risks being incorporated into and acted upon within interventions? How are measures to tackle uncertainty being considered in these processes? How are these processes strengthening partnerships between communities, governments and other stakeholders?

1d

Increase access of all stakeholders to information and support services concerning changing disaster risks, uncertainties and broader climate impacts

How are varied educational approaches, early warning systems, media and community-led public awareness programmes supporting increased access to information and related support services?

2. Enhance adaptive capacity

2a

Strengthen the ability of people, organisations and networks to experiment and innovate

How are the institutions, organisations and communities involved in tackling changing disaster risks and uncertainties creating and strengthening opportunities to innovate and experiment?

2b

Promote regular learning and reflection to improve the implementation of policies and practices

Have disaster risk management policies and practices been changed as a result of reflection and learning-by-doing? Is there a process in place for information and learning to flow from communities to organisations and vice versa?

2c

Ensure policies and practices to tackle changing disaster risk are flexible, integrated across sectors and scale and have regular feedback loops

What are the links between people and organisations working to reduce changing disaster risks and uncertainties at community, sub-national, national and international levels? How flexible, accountable and transparent are these people and organisations?

2d

Use tools and methods to plan for uncertainty and unexpected events

What processes are in place to support governments, communities and other stakeholders to effectively manage the uncertainties related to climate change? How are findings from scenario planning exercises and climate-sensitive vulnerability assessments being integrated into existing strategies?

3. Address poverty & vulnerability and their structural causes

3a

Promote more socially just and equitable economic systems

How are interventions challenging injustice and exclusion and providing equitable access to sustainable livelihood opportunities? Have climate change impacts been considered and integrated into these interventions?

3b

Forge partnerships to ensure the rights and entitlements of people to access basic services, productive assets and common property resources

What networks and alliance are in place to advocate for the rights and entitlements of people to access basic services, productive assets and common property resources?

3c

Empower communities and local authorities to influence the decisions of national governments, NGOs, international and private sector organisations and to promote accountability and transparency

To what extent are decision-making structures de-centralised, participatory and inclusive? How do communities, including women, children and other marginalised groups, influence decisions? How do they hold government and other organisations to account?

3d

Promote environmentally sensitive and climate smart development

How are environmental impact assessments including climate change? How are development interventions, including ecosystem-based approaches, protecting and restoring the environment and addressing poverty and vulnerability? To what extent are the mitigation of greenhouse gases and low emissions strategies being integrated within development plans?

This publication is part of the Strengthening Climate Resilience Discussion Series, which aims to elaborate concepts and application of the Climate Smart Disaster Risk Management approach. All papers are available free to download through the Strengthening Climate Resilience (SCR) website: www.csdrm.org

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For more information contact:
Strengthening Cllimate Resilience
Institute of Development Studies
Brighton BN1 9RE UK
T: +44 (0)1273 606261
info@csdrm.org
www.csdrm.org

IDS Institute of Development Studies
christian aid
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UKaid from the Department for International Development
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