Rapid Desk Based Evidence Search and Gap Analysis on Environmental Degradation and Pollution in Developing Countries

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Introduction

This study has collated information on the role that pollution (focussing on air, water and soil pollution) has played in environmental degradation and the consequences of such degradation for human well-being, poverty. The report has primarily focussed on collating information from investigative studies that have been conducted in DFID priority countries of sub-Saharan Africa; additional information from key studies is also provided for South and South East Asia DFID countries. The information has primarily been gathered from the peer reviewed literature, but also from reports of accredited organisations such as WHO, UNEP, World Bank). The report focusses on literature published over the last 5 to 8 years. The report is not intended to be a comprehensive, systematic review of the literature but rather a review that identifies a number of particular pathways that represent the variety in the bio-physical, socio-economic and political constructs by which pollution and environmental degradation influence human-wellbeing and poverty. To achieve this the report is divided into sections that focus on urban areas (investigating key issues of solid waste, water sanitation & sewerage and energy and air quality) and semi-urban/semi-rural and rural areas (investigating land degradation, with a focus on savannahs and forests as well as contaminant pathways, with a focus on mining, industrial activities and rivers, lakes & coastal waters). The information gathered in the main body of the report is then used to identify key research gaps for the future. The main findings of the full report are summarised in the bullet points below, with the main research gaps summarised in the following 'research gap summary' section.

Main Findings

- The complexity of interactions between pollution induced environmental degradation and poverty is explored in relation to the concept of the *environmental degradation-poverty nexus* (Dasgupta et al., 2005). The bio-physical aspects as well as the socio-economic factors that contribute to this *nexus* are complex, inter-related, dynamic and vary with natural resource and geographical location. It is important to understand these connections, and be able to measure changes in the *nexus* for monitoring and evaluation purposes (Bradshaw et al., 2010). New methods, tools and understanding will be required to achieve this with success.
- Progress has been made in improving key pollution related environmental degradation (e.g. air quality, water sanitation) that has direct impact on human health, and therefore poverty; however, diseases linked to pollution still often rank in the top three leading risk factors of global disease burdens (Lim et al., 2012). The rapid increase in urbanisation in conjunction with poor urban planning will likely confound efforts to eradicate these diseases (Konteh, 2009).
- Poor Municipal Soil Waste (MSW) management continues to cause pollution threatening environmental degradation especially in unplanned urbanisation in many sub-Saharan countries (Ezeah & Roberts, 2012). There is a need to recognise both formal and informal sectors that play a role in MSW management; with informal sectors (sometimes referred to as scavenging or recycling) provide important wealth creation opportunities for the urban poor with benefits for the environment, socio-economic status and progress towards MDGs (e.g. Nzeadibe (2009)). The role of community, governmental and non-governmental organisations in promoting safe activities of this informal sector should be encouraged (Henry et al., 2006).

- Poor sanitation is a primary cause of ill-health of urban dwellers (Sverdlik, 2011), especially those on low incomes; it also causes eutrophication of surface, ground and coastal waters (Nyenje et al., 2013). New methods of utilising waste water (e.g. for urban agriculture (Wichelns & Drechsel, 2011)) may provide win-win solutions that help manage waste whilst at the same time providing nutrient for crops; however, such solutions can also cause additional health risks if not appropriately managed (Mollinga & Bogardi, 2011).
- Indoor and outdoor air pollution, largely arising from the domestic use of biomass and coal contribute one of the leading causes of premature mortality in sub-Saharan Africa and Asia (Lim et al., 2012). Solutions to improve air quality include switching to cleaner fuels and the use of new cook-stove technology (Prasad, 2011). Implementation of access to clean energy policies would also help alleviate energy poverty with additional health benefits across sub-Saharan Africa (Sokona et al. 2012).
- African savannahs are under threat from environmental degradation (Eriksen & Watson, 2009); studies have found such degradation to be associated with globalisation through economic liberalisation often influenced by cultural heritage (S. Eriksen & Silva, 2009). These changes threaten the livelihoods of communities reliant on savannah ecosystems (Clover & Eriksen, 2009).
- Forest degradation continues apace in sub-Saharan Africa due to pressures from fuel wood collection, agricultural expansion and foreign exchange (Darkoh, 2009). Once initiated, forest degradation can fall into a feedback loop reinforcing poverty traps (Khan & Khan, 2009). New mechanisms such as Payments for Ecosystem Services (PES) may help alleviate some aspects of these destructive cycles though it is unlikely the resources these schemes provide would be sufficient to break these destructive cycles (Pattanayak et al., 2010).
- Industrial activities such as mining (Hilson, 2009), tanneries (Mollinga & Bogardi, 2011), oil extraction and transport (Adedeji & Ako, 2009) and agriculture (Adedeji & Ako, 2009) cause sources of a variety of different types and forms of pollution. The drivers of these extractive and productive industries are often associated with globalisation and result in complex socio-economic inequalities within the local communities engaging in the industry (Hilson, 2009). The subsequent pollution causes a variety of impacts on human health and ecological functioning with consequences for human well-being and poverty (Mollinga & Bogardi, 2011).
- Some of the most ecologically sensitive receptors of the pollution sourced from such industrial activities are rivers, lakes and coastal waters, which suffer rather severe environmental degradation (Oguttu et al., 2008; Bouvy et al. 2008). Lake Victoria provides a case in point of the damaging effects of pollution from these activities resulting in eutrophication, heavy metal contamination and enhanced sedimentation with consequences for the livelihoods of local people dependent on the ecosystem services provided by the lake (Oguttu et al., 2008).
- Water borne pollution has also been found to have impacts on livelihoods through damaging fish stocks and hence reducing the viability of small scale fishing industries (Ahmed et al., 2013). To overcome such pollution induced environmental degradation requires management systems to consider social, economic and ecological aspects associated with managing sustainable fisheries (Ahmed et al., 2013).
- The diffuse nature of pollution and its effects in surface and ground water systems has identified the need for pan-national approaches to the management of water resources in Africa (Davies et al., 2012). There is also the need for co-ordination between land and water management although the ideal means of developing and implementing policies to achieve this is unclear (Nkonya et al., 2011).

Research gap summary

The following list identifies broad generic areas that should be prioritised to understand the drivers, bio-physical – socio-economic inter-connections and dynamics of the relationship between pollution induced environmental degradation and human well-being and poverty. These might be suitable areas for which DFID could offer support to ensure that future environmental policy targeting pollution and environmental degradation would achieve maximum benefit whilst also ensure the building of capacities in environmental management in the region and allowing the monitoring and evaluation of the success of a range of interventions.

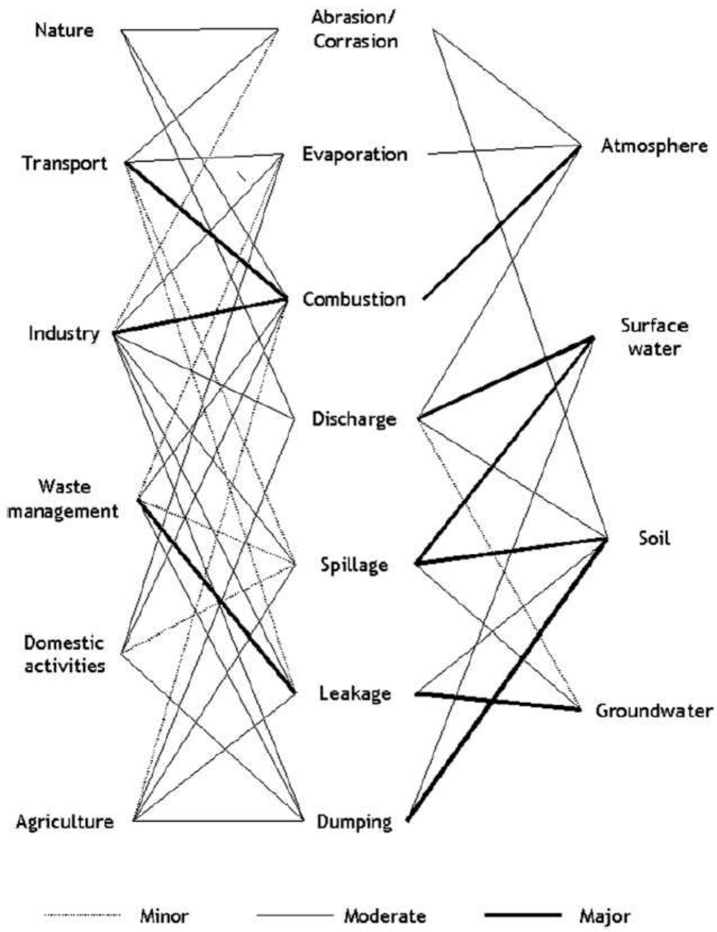
- **Need for an understanding of what drives the pollution induced *environmental degradation-poverty* nexus** – traditional viewpoints that poverty was a major cause of environmental degradation are now seen as being far too simplistic. Additionally a range of variables are recognised as dynamically influencing the extent, longevity and societal sectors affected by pollution induced environmental degradation and human well-being. These are likely to vary by pollution type, geographical location and cultural heritage. They are also likely to change rather rapidly with time as developing economies mature and the effects of globalisation continue to determine socio-economic activities. A full understanding of these drivers would seem essential to be able to predict future threats from pollution and environmental degradation, as well as to develop policies to mitigate or adapt to these threats. For example, there is a need to know how financial liberalization, legal institutions and local and national governance, domestic and foreign markets combine as the drivers of pollution induced environmental degradation.
- **Need for an improved understanding of the multi-dimensional interactions between the pollution induced *environmental degradation-poverty* nexus** – although many studies exist for sub-Saharan Africa and South and South East Asia that describe various types of pollution and its influence on environmental degradation there is a tendency for these to focus on either bio-physical aspects *OR* the socio-economic factors that influence human well-being outcomes; studies that investigate the full 'system' are rather limited. This is perhaps due to data availability and the need for multi-discipline research but the connections of pollution through to poverty can only be truly understood with the availability of such studies. To help improve our understanding of the poverty-environmental degradation nexus investigative studies should be specifically addressing particular natural resources and their connections with poverty alleviation simultaneously. The tendency to generalise across all resource sectors only contributes to the complexity of the subject. Instead socio-ecological studies should focus on i. the users of the natural resource (including behavioural characteristics of each user group as well as their interactions with each other and the natural resource base); ii. the impacts of resource degradation across the user groups and their reactions (adaptation/coping mechanism/management solutions) to these changes; and iii. the dynamics of the natural resource itself.
- **Need for capacity building to provide local communities/national and regional organisations with the tools, expertise and knowledge to understand connections within the nexus and develop appropriate behavioural and policy responses. -** Environmental policy is often out of step with realities on the ground, with governments acting alone often unable to effect the necessary change. Innovative institutional arrangements for pooling financial resources, knowledge and capacity, can help to achieve environmental goals. Improving capacity and equity among diverse communities, including governments, is essential to support collaboration and to secure rights, all of which can help to reduce the effects of pollution on environmental degradation.
- **Need for an improved understanding of the potential solutions to pollution induced environmental degradation problems, ideally with an assessment of their**

multiple benefits (or trade-offs) – poverty is influenced by an extremely wide range of interacting factors which can often have consequential effects to other areas of human-wellbeing as well as suffering positive feedback loops and traps. Identifying these connections and feedbacks can help identify policy interventions that can intervene at the optimum point in the cycle to ensure it breaks. Optimal solutions are likely to be those that address a number of factors related to both poverty and environmental degradation in a mutually beneficial manner. Developing methodologies to allow more holistic cost-benefit assessments of pollution damage and remediation to be performed will provide decision makers with improved knowledge to allow more informed policy interventions.

- **Need for improved data availability and suitably robust and resource efficient monitoring methods for use in understanding the links between pollution, environmental degradation and poverty** - databases describing physical, social and economic data in a consistent spatial and temporal dimension are extremely limited in many parts of Asia and sub-Saharan Africa. These are essential for any robust investigative study into the causes and consequences of pollution induced environmental degradation. Simple methods of pollution monitoring should be investigated and trialled whilst ensuring any data collected is appropriate to understand the influence of environmental degradation on human-well-being within different socio-economic and political settings. Examples of key datasets that are lacking include those describing deforestation (two recent reviews by FAO showed very different trends for 2000-2005) and data to evaluate trends in all water related diseases, currently global data trends on cholera are used as proxy (UNEP, 2012). Datasets that integrate knowledge are also important, for example 'environmental footprints for economic production' at the level of country and product, are required to describe energy and water inputs and key pollution outputs in order to understand how patterns of production and consumption affect environmental systems.
- **The need for improved governance and appropriate international policy approaches -** to ensure globalisation protects against poverty rather than being a driver of poverty. This will become ever more important as population pressure continues to increase over the next 30 years, especially in low and middle income countries; the concept of a 'double leap' in addressing sustainable development and poverty is urgently required. For example, studies assessing the role international trade plays in shaping the 'Pollution Haven Hypothesis', which suggests that emission reductions observed in developed nations are partly the result of shifting 'dirty' production to developing nations with lax environmental standards are useful to better understand the role of globalisation as a driver of pollution and environmental degradation. The benefit of countries working together, for example, through efforts to manage transboundary pollution of air and waters (marine, fresh- and ground-water), should be prioritised given the additional gains that can be made in reducing pollution through these international collaborations. Further research is needed on PES schemes given that a main limitation to the success of these shcemesschemes is often due to poor governance.
- **The need for improved metrics -** to assess the state and dynamics of pollution impacts on natural resources in relation to the environmental degradation-poverty nexus. Is the macro- economic approach of the Environmental Kuznets Curve really helpful in understanding local scale, societal differences in links between environmental degradation and poverty or other metrics required to assess the current state and future trends?

The link between pollution, health, environmental degradation and ultimately poverty is a complex and inter-related process. Most pollutants are of human origin deriving from activities such as industry, energy use and supply, transport, domestic activities, waste disposal, agriculture and recreation. Release of pollutants from various sources occurs in a wide range of ways, and to a range of different environmental media including the atmosphere, groundwater and soil (Fig 1).

Figure 1 Sources and pathways of pollutant emission into environmental media.



The influence of these emissions on environmental degradation is determined by an often complex set of bio-physical determinants specific to different pollutants, media and local conditions. When considering the influence of pollution on environmental degradation, geographical scales are critical with the theoretically appropriate scale being affected by the dispersal characteristics of the pollutant and medium (Dasgupta et al., 2005). For example, particulate pollution from cement mills may only be dangerous in one urban region, whereas eutrophication from fertilizer runoff may affect ocean fisheries a thousand miles downstream from the farms that are the source of the problem. This also confounds efforts to discern cause-effect of pollution-poverty links; for example, if much of the pollutant's impact is felt far downwind or down-stream, failure to find a nexus in the local data may simply mask transboundary effects. However, a large body of evidence indicates that local impacts predominate for pollutants that most heavily affect the poor (Dasgupta et al., 2005).

Finally, the effect of pollution induced environmental degradation on poverty is further confounded by another complex set of interactions and processes. A key question is whether i. poverty causes pollution and hence environmental degradation' or ii. environmental degradation leads to poverty. It is clear that simple causality of the *environmental degradation – poverty nexus*' - mutually reinforcing links between environmental degradation and poverty, are unlikely to exist. The studies collected here show an intricate web of interconnecting factors, variables and feedback loops that determine the *nexus* and hence how this will be affected by pollution of air, water and soil. The socio-economic factors affecting the use of natural resources and hence pollution include: i. typical (neo-classical) economic behaviour i.e. a combination of greed, power and wealth; ii. conflicts between user groups (especially delineated to income); iii. institutions (e.g. governance) or markets (e.g. land tenure and legislative functionalities); iv. demographic and cultural factors; v. globalisation (trade liberalization, economic growth, technology and knowledge transfer). Ultimately, unsustainable use of natural resources may provide economic and human benefit in the short term, but inevitably leads to environmental degradation and poverty, at least for some sectors of society.

As well as understanding the processes that result in the environmental degradation-poverty nexus, it is important to be able to measure the relationships to allow monitoring of responses to alleviate environmental degradation. A number of indices exist to assess environmental performance (Bohringer & Jochem, 2007) as well as some indicators of human well-being. The Environmental Kuznets Curve (EKC) is one such metric that is still receiving much attention as studies attempt to assess its credibility in assessing environmental degradation related to economic growth (Bradshaw et al., 2010). However, a good example of the inconsistency of the EKC approach is given by Orubu & Omotor, (2011) who assessed two different environmental metrics of import for the African region: suspended particulate matter and organic water pollution. They found evidence of an EKC for suspended particulate matter but not for organic water pollutants. A separate study investigating biological oxygen demand as an indicator of water quality found a similar lack of supporting evidence for the EKC in relation to water pollution in Africa and Asia (Lee et al, 2010).

There is a strong link between such ill-health and poverty and inequality. Illness and injury are common causes of poverty in countries where health services are not free, and the inability to work means no income. For example in a study in Dhaka, Bangladesh (cf. (Kjellstrom & Mercado, 2008) ill-health was found to be the most important cause of reduced income and increased expenditure. It led to more loans being taken out, assets being sold and more adults resorting to begging. As such, a useful indicator of the influence of environmental degradation on human well-being, and how this has changed over the past 10 years in line with current development pathways, is provided by the new 2010 Global Burden of Disease (GBD) report (Lim et al., 2012). This study highlights the relative rise of risk factors for non-communicable diseases including metabolic and dietary risk factors. However, in absolute terms the study suggests improvements in factors such as water and sanitation (with reductions in diarrheal diseases) and environmental contamination (with reductions in tuberculosis). Pollution remains a leading cause of risk of these diseases. For example, the continued threat from household air pollution is evident with this being the leading cause of Disability Adjusted Life Year (DALYs) in many parts of South Asia and sub-Saharan Africa; poor sanitation remains a primary cause of diarrheal diseases.

The following sections, divided into i. Urban areas and ii. Semi-urban, semi-rural and rural areas investigate a number of key challenges related to pollution, environmental degradation, human well-being and poverty primarily facing sub-Saharan Africa (but also including parts of South and South East Asia). The investigation focusses on peer reviewed literature sources published in the last five years that specifically discuss air, water and soil pollution in relation to environmental degradation and some aspects of human development.

Summary reports have largely been excluded from this list on the proviso that these would be readily accessible and that the goal of this study was to collate the more disparately located recent literature.

Urban Areas

The effect of environmental degradation on poverty, economic growth, health and human development in urban areas is discussed, as appropriate, in the following sections on i. water sanitation and sewerage and ii. transport & energy. These key issues were selected to incorporate a wide spectrum of environmental degradation and poverty interactions and due to their importance in human well-being. The potential solutions to the challenges arising from these problems are also considered.

Water Sanitation and Sewerage

Due to rapid urbanisation and the lagging behind of improved sanitation facilities in sub-Saharan Africa, 180 million individuals in 2010 are still affected by lack of sanitation facilities, more than double those in 1990.

Health Issues – Poor sanitation results in low income segments of the urbanised population suffering a high incidence of water quality/sanitation related diseases (e.g. diarrhoea, cholera) and malaria (vector borne disease) (e.g. Sverdlik, 2011). However, there appears to be little evidence of absolute health penalties due to urbanisation as compared to rural environments, especially for children (Leon, 2008) due to a range of factors, including better vaccination and health coverage, better information and better nutritional intake, even in low income sectors of urban as compared to rural inhabitants. Irrespective of the relative differences between urban and rural inhabitants, the impact of poor sanitation on ill-health remains high on the international organisation agenda. The United Nations Development Programme World Human Development Report 2006 recognised that 'water and sanitation are the most powerful preventive medicines available to governments to reduce the rate of infectious diseases' (UNDP, 2006). The WHO/UNICEF Joint Monitoring Programme confirmed that although national and international agencies and non-governmental organisations have accelerated efforts to meet the 'access to safe water and basic sanitation' MDG, achieving this goal is still a long way off (cf. Mollinga & Bogardi, 2011).

An example of the current state of sanitation in urban cities in sub-Saharan Africa is given by Boadi & Kuitunen (2005) for Accra in Ghana. Accra is faced with severe inadequacy of urban infrastructure in the face of rapid population growth in the metropolis. More than half of the city's population do not have access to solid waste collection services. Only 39.8% of households have indoor pipe and over 35.0% of households depend on unsanitary public latrines whilst 2.5% do not have access to toilet facilities. Human excrement, garbage and wastewater are usually deposited in surface drains, open spaces and streams in poor neighbourhoods. The resultant poor sanitation has serious health impacts as more than half of reported diseases are related to poor environmental sanitation. A study by (Konteh, 2009) highlights these inequalities amongst urban residents stating that it is not urbanisation *per se*, but the phenomenon of ever increasing number (and proportion) of urban residents living in abject poverty in South and East Asia, and sub-Saharan Africa (UNFPA, 2007) along with the growing wealth inequalities, that disadvantages the urban poor causing them to suffer poor sanitation and consequent ill-heath.

The term 'wastewater' is used to characterise different qualities, ranging from raw to diluted sewage generated from various urban activities. These activities range from domestic, commercial, industrial, stormwater and urban run-off, treated wastewater, reclaimed wastewater, faecal sludge and biosolids. The lack of proper on-site sanitation in un-sewered low income areas results in high levels of morbidity and mortality due to communicable diseases, such as cholera, typhoid, dysentery, and tuberculosis; these diseases are common in low income cities and linked to poor sanitation, inadequate waste disposal system and water supply provision, poverty and deprivation (Konteh, 2009). Almost half the population in Africa and Asia suffer at least from one disease attributable to the lack of safe water and adequate sanitation and young children are at particular risk (see Table 1). These health hazards are not necessarily related to poor quality drinking water but also to the daily exposure to polluted water and sewage (skin contact, inhalation and indirect consumption) (Mollinga & Bogardi, 2011).

Estimates of the proportion of people without adequate provision for water and sanitation in urban areas, 2000

	Number and proportion of urban dwellers without adequate provision	
Region	**Water**	**Sanitation**
Africa	100–150 million (~35–50%)	150–180 million (~50–60%)
Asia	500–700 million (~35–50%)	600–800 million (~45–60%)
Latin America and the Caribbean	80–120 million (~20–30%)	100–150 million (~25–40%)

SOURCE: UN–HABITAT (2003b), *Water and Sanitation in the World's Cities: Local Action for Global Goals*, Earthscan, London.

Table 1 Estimates of the proportion of people without adequate provision for water and sanitation in urban areas, 2000. cf. (Kjellstrom & Mercado, 2008).

For example, a study by Osei et al. (2010) concluded that surface water pollution resulting from such wastewater sourced through runoff from waste dump sites, played a significant role in cholera infection in an urban area in Kumasi, Ghana. Cholera has been a public health burden in Ghana since the early 1970s. Between 1999 and 2005, a total of 25,636 cases and 620 deaths were officially reported to the WHO. Kumasi is one of the worst affected urban cities, surface runoff from dump sites is a major source of faecal and bacterial contamination of rivers and streams leading to high levels of faecal contamination in surface waters, the study by (Osei et al., 2010) made clear associations, using GIS spatial mapping between high instances of cholera among inhabitants living in close proximity to surface water bodies.

Environmental degradation issues – Poor sanitation can also lead to nutrient rich waste-water leaching to ground water and potential eutrophication (Wriege-Bechtold et al. 2009) (Nyenje et al., 2013). For example, wastes from pit-latrines that remain a common feature of Nigerian towns and villages also contribute to pollution of water bodies. This has consequences which include scarcity of oxygen for aquatic animals and leads to their death and further pollution of the water. Many water bodies that flow through many of Nigeria's cities and urban centres are polluted in this way (Adedeji & Ako, 2009).

Inadequate onsite sanitation systems are also associated with groundwater pollution through leaching of wastewater contaminants into underlying aquifers, which contribute to microbiological contamination of water sources and increased nutrient concentrations (nitrogen, N and phosphorus, P) and discharges to downstream ecosystems.

For much of sub-Saharan Africa (SSA), there is still a large knowledge gap regarding the loads and processes controlling the transport of faecal contaminants in groundwater. Failure to address this pollutant source contributes to increasing nutrient pollution of groundwater and the subsequent eutrophication of surface-water bodies. For example, Nyenje et al. (2013) studied the dissolved nutrient loads (nitrate, ammonium and orthophosphate) and the processes likely affecting them in aquifers underlying two on-site sanitation systems in un-sewered low-income urban slums in Kampala, Uganda: a domestic solid waste dump and a site with two pit latrines. They found that substantial amounts of nutrient enriched wastewater originated from the pit latrine and infiltrated the aquifer, by contrast, pollution from the waste dump was substantially less. Pit latrines are the dominant mode of excreta disposal for Kampala City and other areas of sub-Saharan Africa suggesting problems with groundwater contamination and downstream eutrophication may be widespread. The use of elevated pit latrines, the installation of biogeochemical filters of fine loamy clayey soils around the pit, the adoption of urine diverting dry toilets (UDDTs) and the use of pit additives to increase loss of N by volatilization could help reduce contamination, especially in areas with a shallow water table (Nyenje et al., 2013).

Potential solutions and associated threats - The combination of health and environmental degradation impacts resulting from unmanaged wastewater discharge means that the impacts of poor sanitation on human health and the impacts on environmental variables should be considered holistically to provide a truly encompassing human health assessment (Shandra et al., 2011). Increasingly sewage is recognised for its potential re-use in design of water management systems. Solutions include the use of greywater (treated for laundry and to flush toilets), brownwater (biogas for heating cooking and power), and yellowwater (use as mineral fertiliser) (Wriege-Bechtold et al., 2009). For example, well documented research on waste water re-use in peri-urban and urban areas of West Africa (Wichelns & Drechsel, 2011) has shown the significant contribution of benefits in horticulture to local urban markets by use of sewage water (brown/grey water). The greatest challenge is that making use of waste water be done in such a way that does not threaten health and human safety, and that safety measures are embedded in the production-consumption chain of waste water re-use.

Closing water cycles by treating and recycling industrial water is urgently needed to prevent the negative health consequences of economic growth. Instead, the increasing disposal of wastewater into water bodies and reuse in agriculture can be observed. A rough estimate indicates that at least 20 million hectares in 50 countries are irrigated with raw or only partially treated wastewater (Mollinga & Bogardi, 2011). The potential for wastewater irrigation and its benefits and risks are examined. These include crop productivity, aquaculture, soil health, groundwater quality, environmental health, public health, infrastructure constraints, social concerns and risks, property values, social equity, and poverty reduction. It is argued that, wastewater reuse and nutrient capture can contribute towards climate change adaptation and mitigation. Benefits such as avoided freshwater pumping and energy savings, fertilizer savings, phosphorous capture and prevention of mineral fertilizer extraction from mines can reduce carbon footprints and earn carbon credits. Wastewater reuse in agriculture reduces the water foot- print of food production on the environment; it also entails activities such as higher crop yields and changes in cropping patterns, which also reduce carbon footprint. However, there is a need to better integrate water reuse into core water governance frameworks in order to effectively address the challenges and harness the potential of this vital resource for environmental health protection (Hanjra et al., 2012).

Urban agriculture needs to follow sustainable development, for example, a study by Sangare et al., (2012) in West African urban agricultural system found scope to substantially reduce nutrient application rates in these systems without adverse effects on yields. Novel production methods may well help to overcome these challenges whilst also providing partial solutions to sanitation problems. Excreta are known to contain valuable nutrients as well as organic matter (OM). Municipal solid waste was also reported to contain substantial amount of plant nutrients. Co-composting of faecal sludge and organic municipal solid waste allows recycling of nutrients into agriculture thereby closing the nutrient loop and provides a good mix of nutrients for plants (Cofie et al., 2009).

There are also opportunities for the role of informal urban and peri-urban irrigation (Wichelns & Drechsel, 2011). Many farmers in developing countries use treated or untreated wastewater to irrigate crops, partly in designated irrigation schemes, but mostly on large areas of small farms located along streams passing through or near cities. Much of the wastewater use is informal and unplanned, as farmers divert water from streams that carry untreated or partially treated effluent from cities and towns. However, wastewater irrigation also creates health risks for farmers, their families, and consumers. A particular concern is the risk to human health from the exposure to high levels of faecal coli from bacteria, worm eggs and trace organic compounds. These health risks vary depending on the different forms of exposure that diverse social groups face with reports of fevers, diarrhoea and sores on the hands and legs of farmers and labourers exposed to wastewater (cf. Mollinga & Bogardi, 2011).

There are also concerns over the use of wastewater and impacts on agricultural produce. For example, the cause of the 1970 cholera epidemic in Jerusalem and typhoid epidemics in Santiago and in 1987 in Dakar were all associated with raw vegetables produced in urban and peri-urban agricultural areas (cf. Mollinga & Bogardi, 2011). Children of farmers or farm workers, who do not have a built up immunity, tend to be most at risk to gastrointestinal problems. In terms of environmental impact, the use of wastewater, especially from industrial sources, over a long period of time can result in heavy metal accumulation. People first get skin diseases when regularly exposed to wastewater. Unfortunately for some, this skin disease transforms into chronic and severe skin infections due to diabetes which weakens health over a period of time, sometimes leading to death. Similar is the case when undernourished people are exposed to filthy wastewater, exacerbated by poorly ventilated housing and substandard work atmosphere. They are prone to tuberculosis leading to early death. The effects of unhygienic environmental and physiological factors have not been adequately examined by scientific communities in fast growing economies (cf. Mollinga & Bogardi, 2011).

The long-term use of wastewater can become self-limiting due to soil damage. Although the organic matter in wastewater can improve soil texture and water-holding capacity, it has harmful effects, particularly in arid environments by causing soil salinisation, blocking soil interstices with oil and grease and accumulating heavy metals. In Pakistan, over-use of wastewater with insufficient drainage (also the case with freshwater irrigation) has produced signs of degradation of the soil structure, visible soil salinity and delayed emergence of wheat and sorghum due to excess nutrients. (Mollinga & Bogardi, 2011).

Public officials must consider those risks and the values generated through wastewater irrigation, as they implement policies to protect farmers and consumers from the negative health impacts. Given the increasing scarcity of fresh water in many urban and peri-urban areas of developing countries, the increasing demand for food, and the persistent desire to improve the livelihoods of small-scale farmers, the decisions faced by public officials will require careful analysis. To that end, the economics, finance, business opportunities, and methodological constraints that pertain to wastewater irrigation in developing countries would ideally be developed using an appropriate multi-stakeholder approach to ensure provision and use of clean irrigation water (Veenhuizen & Larbi, 2008).

Solid Waste

The poor state of municipal solid waste (MSW) management in cities in developing countries is rapidly becoming a major social and environmental challenge. Ezeah & Roberts (2012) found that the main drivers of the MSW problem in Nigeria were poverty, rapid population growth and urbanisation rates, compounded by a weak and underfunded infrastructure. For example, a study by Henry et al. (2006) confirmed the importance of poor economic growth rates which has led to an increase in poverty levels, currently standing at 56% in 2006 in Kenya. Migration from rural to urban areas in Kenya has resulted in unplanned settlements in suburban areas accommodating about 60% of the urban population on only 5% of the urban land. Political interference has also hampered the smooth running of local authorities. Vulnerability of pollution of surface and groundwater is high because local authorities rarely consider the environmental impact in siting MSW disposal sites. Illegal dumping of MSW on the river banks or on the roadside poses environmental and economic threats on nearby properties. In addition, poor servicing of MSW collection vehicles, poor state of infrastructure and the lack of adequate funding militate against optimization of MSW disposal service (Henry et al., 2006).

The severity of the MSW problem across many developing countries is reflected in the attention it received in the United Nations Millennium Declaration, in 2000: three of the eight Millennium Development Goals (MDGs) have waste or resource efficiency dimensions. In response to the challenge of MSW, many developed countries have sought to achieve ambitious environmental reforms, leading to improvements in the management of MSW. However, this is not true of most countries in sub-Saharan Africa, due to several barriers. Ezeah & Roberts (2012) conducted a survey of 1,557 respondents drawn in Abuja, Nigeria. Their findings suggested the need for a sustained public education programme on waste prevention and re-use. They called for the adaptation of globally successful MSW best practises and strategies to suit local conditions.

A number of studies highlighted the importance of both public and private, formal and informal (sometimes referred to as scavenging) sectors of MSW management (Noel, 2010; Gutberlet, 2012; Oteng, 2012). Informal management may actually play a large and important role in MSW management both from a pollution, and therefore environmental point of view, as well as a social perspective. For example, Nzeadibe (2009) studied MSW management reform and informal recycling in Enugu, Nigeria. This study examined the role of the informal recycling sector in the planning and reform of MSW management in Enugu. The study highlighted the important contribution of informal recyclers to managing Enugu's solid waste problem, as well as job creation and poverty alleviation. Nzeadibe (2009) argues that the importance, and the development potential, of the informal recycling sector has not been sufficiently recognised within the framework of the reforms in MSW management, despite the focus of the MDGs on poverty reduction, improvement of quality of life and environmental sustainability. Official recognition and support for recycling as well as the empowerment of people involved in these activities could help to improve MSW management. The identification of the socio-economic importance of informal recycling of MSW was also identified by (Oteng, 2012) in Gama, Ghana where for most of the urban poor, waste collection and recycling is a common source of livelihoods, with the practice having become a survival strategy for thousands among the urban poor. The proper integration of the sector into the existing MSW management policies could lead to sustainable management practices and could help to alleviate poverty yet this potential is not yet realised by the authorities. There are also gender aspects to such scavenging; (Rockson et al., 2013) found that scavenging in the Greater Accra region of Ghana is carried out mainly at landfill sites and commercial areas of the city, and is a male-dominated activity. Materials recovered include plastics and metals such as iron, copper and aluminium. On average, scavengers earn between US $7 and US $17 per day depending on the items recovered and market trends. Their average daily earnings surpass the US $1 a day target for poverty reduction under the MDGs. The activities of scavengers contribute to waste recovery and recycling through their sorting and cleaning activities. Again (Rockson et al., 2013) concluded that local authorities in Ghana could improve waste recycling and resource utilisation if they recognised scavengers of waste materials as important stakeholders in the MSW management sector.

However, these informal MSW activities are not without health hazards, a study conducted in Brazil (although with applicability elsewhere) by Gutberlet (2012) found that their work is subject to health risks, accidents and exploitation. These risks could to some extent be reduced through the establishment of organised cooperatives, associations or social enterprises for the recyclers. These collectives provided important spaces for social inclusion and human development, by promoting meaningful work, increasing workers' self-esteem and improving their living and working conditions. Resource recovery and recycling also generated net carbon credits, which could be redirected towards this sector.

An important emerging threat to this informal sector was also identified by Gutberlet (2012). The recent introduction of waste-to-energy technology was perceived as a threat to the recyclers' livelihoods. Incineration does not generate income, produces environmental contamination and competes with other forms of waste management. The study concluded that organised recycling could generate social, economic and environmental benefits and radically address poverty reduction. Remunerating the recyclers for their service and considering the environmental gains of their work (through the Clean Development Mechanism) contributes to the MDG of poverty alleviation.

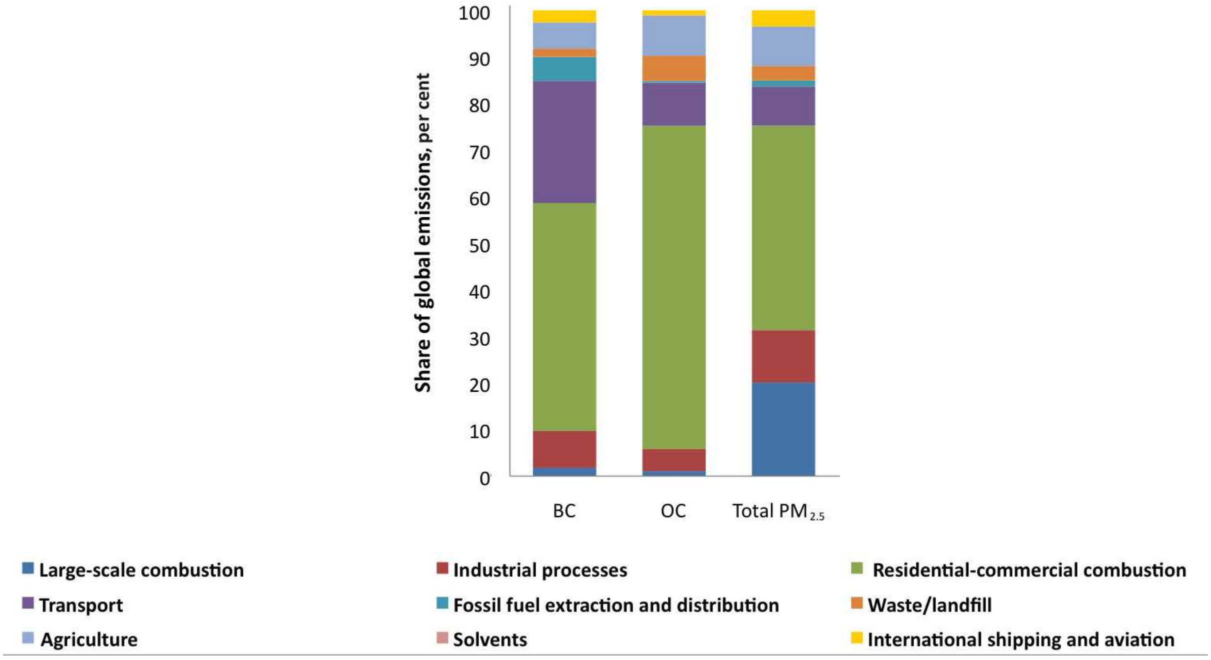
In summary, many of these studies on MSW management identified the need to recognise both formal and informal MSW management and develop governance systems appropriately. For example, Henry et al. (2006) argued that involvement of this full variety of stakeholders is important to achieve any meaningful and sustainable MSW management. They also showed the importance of collaborations between community-based organisations (CBOs), non-governmental organisations (NGOs) and the private sector in improving the management of MSW. Similarly, Gutberlet (2012) emphasised the importance of participatory MSW management in changing 'closed loop' economies and encouraging more sustainable communities at a global scale.

Energy or Urban Air Quality

This section focusses on **outdoor and indoor air pollution** and environmental health. Although this sits within the urban areas section it should be noted that the air quality problems associated with energy use are similar in communities in rural areas, where the sheer mass of diffuse polluting sources can lead to poor air quality that can rival many urban areas. Outdoor and indoor air pollution is a major threat to human health in sub-Saharan Africa and South Asia as evidenced from data presented in the 2010 Global Burden of Disease study (Lim et al., 2012). For example, in central, eastern and western sub-Saharan Africa, the share of disease burden attributable to household air pollution from the use of solid biomass fuels has fallen substantially but still remains one of the three leading causes of disease burden in 2010.

Sources of particulate matter (PM) air pollution - A primary driver of such pollution is the more than 3 billion people, living in both rural and urban areas, dependent upon solid fuels including biomass (wood, dung, and agricultural residues) and coal to meet their most basic energy needs (WHO report 'Fuel for Life'; Rehfuess, 2006). Other sources of this air pollution include desert dust (De Longueville et al. 2013); landscape fires (Johnston et al., 2012) and open biomass burning (Rao et al., 2012). A recent UNEP/WMO (2010) report summarised the global share of particulate matter (PM); the most harmful air pollutant to human health) by region showing that Africa and Asia make up some 30% of the total global PM emissions. The sectors from which these PM emissions originate are shown in Fig 2; this highlights the importance of residential commercial combustion (representing ~40% of total PM emissions).

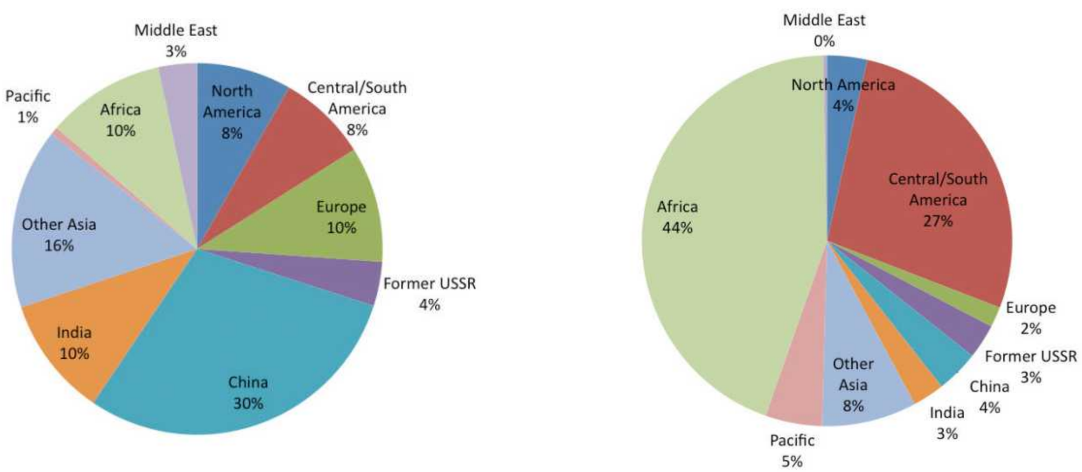
Figure 2 Sectoral shares of global anthropogenic PM emissions for 2005. UNEP/WMO (2010).



N.B. the fractions of BC (black carbon) and OC (organic carbon) are also shown since these were important for the report which investigated the impact of PM on human health as well as near term climate change, BC being a positive radiative forcer.

The contribution from different world regions to PM is indicated by Figure 3 which shows the distribution of global black carbon (BC) (an important component of PM; see Figure 2) from two different combustion sources. Asia predominates the contained combustion (essentially anthropogenic burning) source with 56% of global BC sourced from this region whilst Africa is the primary source of open biomass burning BC at 44% of the global burden. The transport sector's contribution to the global total PM load is ~10% though this is likely to be higher in developing countries due to older and more polluting vehicle fleets.

Figure 3 Distribution of global BC emissions by world region for contained combustion (left) and open biomass burning (right).



The main sources of PM in Africa and Asia, as globally evidenced from Figure 2, are from energy related emissions from the residential sector due to the use of biomass and coal in cooking (Rao et al., 2012). The proportion of household biomass use varies among neighbourhoods and is generally higher in low socio-economic status communities (Zhou et al., 2011). This can have implications for human exposure to air pollution since it was found that community biomass use had a stronger association with household PM than households own fuel choice (Zhou et al., 2011).

Health impacts - A range of health impacts are associated with increased PM and particularly the use of solid fuels for cooking, these include increased pneumonia risk in children under 5 years (Bruce, 2008; Sumpter & Chandramohan, 2013), acute lower respiratory infections (Rehfuess et al., 2009; Sumpter & Chandramohan, 2013), chronic obstructive pulmonary disease and lung cancer among adults (Sumpter & Chandramohan, 2013). In relation to cooking, studies have found differences in acute lower respiratory infection mortality risk in African children in relation to cooking practices with stove ventilation being an important means of reducing indoor air pollution and hence premature mortality (Rehfuess et al., 2009).

Over reliance on firewood and charcoal for cooking not only causes mortalities through indoor air pollution but also contributes to high rates of deforestation and is likely to cause additional ill-health to women and children who carry the heavy burden of fuel wood collection (Rao et al., 2012).

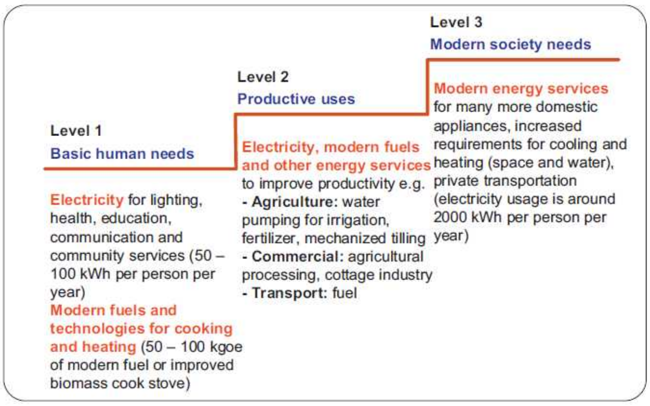
Potential solutions to improve air quality, improve energy security and reduce poverty – The use of cleaner fuels and stoves in domestic energy provision can make a substantial improvement in both indoor and outdoor air quality. However, barriers to making these changes are strongly connected with poverty. Increasing income levels of the poor have been identified as urgent requirements to facilitate fuel switching to cleaner fuels such as liquefied petroleum gas (LPG) and kerosene as well as biogas and electricity (Prasad, 2011); as well as the use of improved stove technology (Ochieng et al. 2013; Okello et al., 2013; Lewis & Pattanayak, 2012). Identifying and increasing access to such new technologies is one thing, having people actually make the switch to new fuels and stoves is another challenge due to cultural attitudes (Akpalu et al., 2011). Lack of regular physical access to clean fuels was also found as a key obstacle to fuel switching in low income neighbourhoods and should be addressed though equitable energy infrastructure (Zhou et al., 2011) . These findings suggest the so-called *fuel-ladder* is not robust (i.e. households do not progress from biomass to kerosene to LPG as their living conditions improve).

A comprehensive review of empirical studies investigating the uptake of improved cook stoves and clean fuels found evidence of a relationship between adoption of clean energy products and socio-economic status and urban location suggesting that strengthening the communication aspects of social marketing and extending the supply chain into rural areas could increase adoption (Lewis & Pattanayak, 2012); such factors will of course also determine the geospatial distribution of pollution emissions and hence poor air quality, with lower income households areas experiencing the worst environmental conditions.

Given that the switch to cleaner fuels will likely take some time to achieve in its entirety due to challenges associated with infrastructure, economics and local culture, Maes & Verbist, (2012) also call for increasing the sustainability of the current traditional biomass systems. They argue this can be realised by an integrated approach, in which national and regional fuel wood policies are adapted, improved systems for charcoal production are implied and improved stoves, in combination with chimneys, are distributed; such policies could improve air quality as well as lead to reductions in forest degradation.

The practice of widening modern energy service access to the poor in Africa, and thereby reducing air pollution associated with energy provision, is complex, and exacerbated by the dual nature of energy systems across sub-Saharan Africa i.e. the need to improve the livelihoods of the poor whilst also using modern energy to drive local economic development (Sokona, 2012; see Figure 4). Solutions such as the use of biogas can also serve the dual purpose of reducing environmental pollution and generating energy providing a village-scale technology that could offer the technical possibility of more decentralised approaches to development in Africa (Amigun & von Blottnitz, 2010).

Figure 4 Incremental levels of access to energy services (cf. Sokona, 2012).



The resulting energy poverty is a large contributor to poor air quality can adversely affect public health, not only due to indoor and outdoor air pollution and physical injury sustained during fuel wood collection, but also due to lack of refrigeration and medical care in areas that lack electricity. Energy poverty affects both the gender roles within society and the educational opportunities available to children and adults; the environmental impacts of energy poverty encompass deforestation and changes in land use, as well as the emission of greenhouse gases. Therefore, the structural elements of the global energy system that entrench and sustain energy poverty need to be challenged and removed (Sokona, 2012).

Semi-urban/semi-rural and rural areas

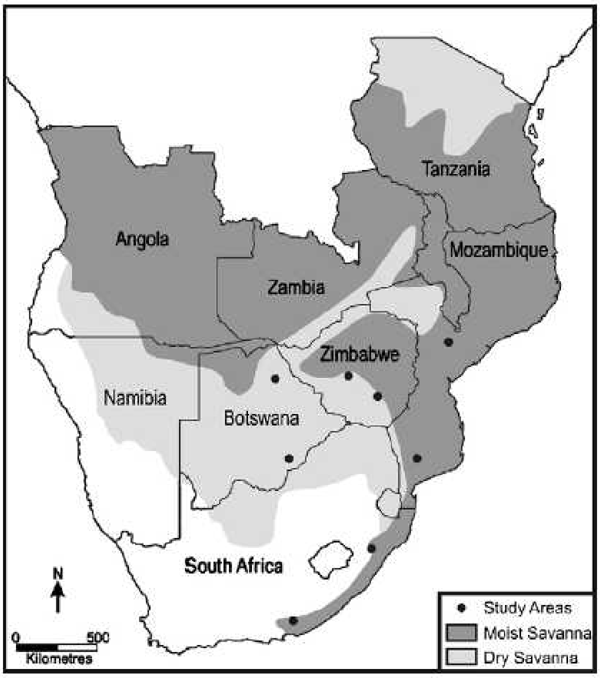
This section targets two key areas: land degradation (with a focus on savannahs and forests) and contaminant pathways (with a focus on mining as well as rivers, lakes and coastal systems) investigating each from their role in environmental degradation, poverty and household and national scale economic growth. These areas are selected for their diversity in relation to the multi-dimensional constructs that will affect their specific environmental degradation-poverty relationships thereby providing a range of examples.

Land Degradation

This section focusses on the degradation of two widespread ecosystem types that are crucial in supporting human development: i. Savannahs, common across large parts of southern Africa (see Figure 5) and ii. Forests (important both in sub-Saharan Africa and South Asia). Degradation of both these systems has been reported on extensively in the scientific literature with efforts made to identify and understand the processes that relate such environmental degradation to human well-being, poverty and the consequent sustainable use of these resources upon which communities rely for livelihoods, energy and water security. Biodiversity is identified as an important factor related to land degradation and the ability of land resources to support communities, in parts of sub Saharan Africa biodiversity is routinely threatened by climate change, pollution, introduction and invasion of alien species, poaching, hunting and illegal trade, government policies that encourage cash crop production for export, forestry and human settlement in previously natural habitats and the appropriation or nationalization of land by the State (Darkoh, 2009).

Savannahs - Savannahs constitute the most spatially extensive eco-zone in southern Africa (Figure 5) and are home to most of the region's wildlife, livestock and human populations. The savannahs play a key role in sustaining environmental services, livelihoods and economic growth in the region. Increasing reports of diminishing resources and reduced capacity to respond to change has motivated the need to identify the main threats and opportunities to savannah stability. A study by Eriksen & Watson (2009) found a variety of processes that were responsible for the economic, social and environmental changes in sustainability; these were more diverse than those traditionally discussed within degradation and livelihood debates and included: increase demand for biofuels, the invasion of alien species, the increase in game farming, and increased peri-urban informal settlement and livelihoods. The changes in savannah sustainability were very strongly related to changes in the dynamic biophysical environment in terms of indigenous flora and fauna with changes in this biophysical environment both driving, and being dependent upon, other processes of change. While many of the changes within savannahs reinforce each other, many of the key driving factors of change are generated externally through factors such as economic globalisation and climate change; this led Eriksen & Watson (2009) to conclude that measures intended to strengthen the sustainability of savannah regions should be targeted at the national or regional scale rather than being restricted to processes internal to savannahs such as cultivation on unsuitable areas.

Figure 5 Savannah extent and study sites within Southern Africa (cf. Eriksen & Watson (2009)).



This point was investigated in more detail by Eriksen & Silva (2009) who focussed on economic globalisation and the effect that associated changes such as economic liberalisation (leading to increasing international trade, commercialisation and export orientation) had on vulnerability of households located in the Mozambique savannah. They noted that economic liberalisation can introduce new forms of risk (e.g. commodity price fluctuations and privatisation of former state owned enterprises) into previously subsistence based economies as household incomes become more volatile. The study showed that although economic liberalisation caused an increase in informal trade and casual employment opportunities, when combined with period of severe drought stress small holders found themselves locked into activities that barely secured economic survival and sometimes endangered long-term response capacity. Only a few large-scale farmers had the skills necessary to negotiate a good market position in urban markets, thus securing future incomes. Again this highlighted the close linkage within savannah eco-zones of inequality, social sustainability, vulnerability and natural resources.

Clover & Eriksen (2009) found that inequitable distribution of land and colonial legacy of dual or pluralistic systems of tenure are at the root of many agrarian and environmental problems in Southern African savannahs. Post-independence land reforms have largely failed to address these fundamental issues, sometimes even reinforcing threats to social, economic and environmental sustainability. The skewed distribution of land and resources, insecure rights, and the marginalisation and restriction of savannah livelihood systems have persisted, undermining human security and environmental integrity in the region as well as leading to mounting conflict and insecurity; these factors need to be considered when developing solutions to ensure future sustainable use of savannah ecosystems.

Forests - An FAO study estimates forest loss each year in Africa at 5.3 million hectares (cf. Darkoh, 2009); deforestation in southern Africa countries results from fuel wood collection by poorer communities, overexploitation of forest resources for foreign exchange, planting of crops such as tobacco.

A study by (Norris et al., 2010) investigated biodiversity within the forest-agriculture mosaic that exists in ~80% of the original forest area of West Africa. These highly modified forests provide food, fuel and fibre and a range of ecosystem services for over 200 million people which means the future biodiversity of the region is intimately linked with the with the lives and livelihoods of local people. The forest loss and degradation across the region has been caused primarily by agricultural expansion as well as wood extraction; both contriving to reduce forest tree cover and simplify vegetation structure reducing biodiversity. Biodiversity conservation in the region is becoming increasingly embedded within a more multi-functional view of agricultural-forest mosaics recognising the value of the full range of services provided by such land-cover constructs; the additional revenue that can be generated by tree cover through carbon trading and certification schemes may help re-shape the drivers of landuse change. An understanding of the drivers of change in West Africa may help develop policies and practices that could avoid comparable levels of forest loss and degradation in Central Africa over coming years.

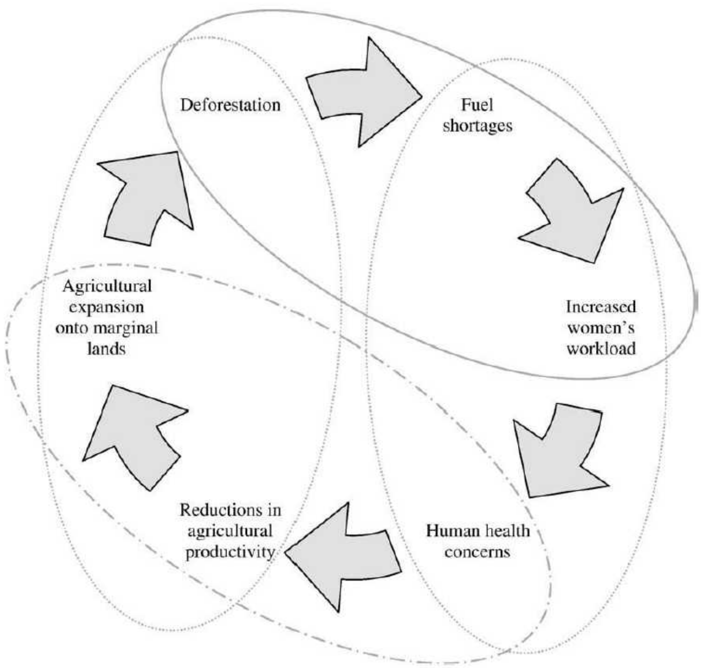
The debate on the links between poverty and forestry degradation were investigated by (Khan & Khan, 2009) challenging the rather commonly held view that, due to poverty and the meeting of subsistence needs, the poor use natural resources more intensively and hence cause them to degrade. Khan & Khan (2009) studied the forest rich Swat district in Pakistan, and did not find empirical support for the “poverty–environment nexus”. Rather, they found that the poor and other income groups were equally resource dependent; they also showed that resource degradation was not associated with poverty. Historical and institutional analyses provided alternative explanations for resource degradation finding that selective and rotating ownership patterns, starting in the 17th century, provided limited incentive for resource conservation. These changing ownership patterns also created tensions between *de jure* and *de facto* owners that were an important source of forest degradation; ill-defined resource rights have also exacerbated the impacts of several other factors contributing to forest degradation which are compounded by poor management, corruption, and perverse incentives.

While the theory of PES is relatively straightforward (to internalise environmental externalities), the practice is much more difficult, particularly in developing countries, which face a plethora of institutional design and governance challenges (Pattanayak et al., 2010);

in addition it is unclear whether such schemes really provide an improvement in environmental services, all other things being equal. They argue that we do not yet fully understand either the conditions under which PES has a positive environmental and socioeconomic impact or its cost-effectiveness; this is partly related to a dearth of evidence due to the short lifetime of PES as an applied concept. Ideally PES programmes would, at their outset, be designed to with the intention of evaluating their effectiveness.

Studying the dynamics of land-use and -cover change and land degradation in the Central Rift Valley in Ethiopia, Reynolds et al. (2010) found that local stakeholders identified firewood shortages, degradation of croplands, rising lake levels encroaching on croplands and poor water quality as major impediments to development. They further identified ecological degradation as a key component of these problems, and they acknowledged multiple vicious cycles (see Figure 6) compounding the environmental and economic threats to the local Awassa community. Proposed solutions included investment in natural capital in the form of reforestation activities, investment in human capital in the form of promoting more efficient wood stoves along with increasing public awareness of environmental threats, and investments in social capital in the form of inter-institutional coordination to address environmental problems. All recommended investments rely primarily on national resources, in distinct contrast to the extensive imports required for most built capital investments. Reversing the ecological degradation on the scale necessary for sustained economic development in Ethiopia will require a steady flow of substantial investments, and cannot rely solely on short term generosity of funders. International payments for carbon sequestration and other ecosystem services could help provide the necessary resources to help break cycles of poverty, sickness and environmental degradation with cycles of knowledge, health and life (Reynolds et al., 2010) though often the payments are not sufficient to allow people to get out of poverty in a sustained manner.

Figure 6 Extended deforestation feedback loop. Ovals indicate relationships that were explicitly identified by one or more stakeholders. Several such "extended" feedback loops can be identified from the problems and perceived casual pathways



Tropical countries face special specific problems in implementing sustainable forest management (SFM) (Karsenty et al., 2008) with questions raised as to whether tropical forests should be publicly, commonly or privately owned and managed in order to enhance sustainability. Other debates also focus on whether small-scale enterprises are better positioned than large-scale industrial concessions to reduce poverty and attain sustainable management. In countries where large tracts of forest are state-owned, concessions are viewed as a means of delivering services of public and collective interest through an association of private investment and public regulation. However, the success of an industrial concession model in countries with large forest resource endowment to achieve multiple goals such as sustainable forest management and local/regional development depends on two critical assumptions. First, forest functions and services should be managed and maintained as public goods. In many cases, additional uses – and corresponding rights – can take place alongside logging activities. Industrial concessions can be more efficient than other tenure models (such as community-based forest management and small-scale enterprises) in achieving SFM, add value to raw material and comply with growing environmental norms. This is especially the case in market-remote areas with low population density and poor infrastructure. Secondly, to achieve these different outcomes, any concession system needs to be monitored and regulated, especially in contexts dominated by asymmetrical information between regulating authorities and concessionaires. New institutional responses have recently been put forward in several countries, providing valuable materials to design a renewed policy mix which associates public and private incentives. A study by (Karsenty et al., 2008) described the results of a survey of the experience of forest concessions in several Central African countries and argues that despite a sometimes patchy record, concessions can help promote SFM so long as they are packaged with a certain number of specific measures (e.g. certification schemes). In a situation characterised by unclear land rights and subsequent risks of forest conversion to create *de facto* individual land rights, a concession regime can fill the vacuum created by a confusing land tenure situation in order to contribute to forest protection against conversion.

A high level of land degradation is the only factor that has been consistently proven to significantly increase the risk of civil conflict although this result should be treated with caution (Theisen, 2008). Poverty and dysfunctional institutions were robustly related to conflict; the distribution of resources relative to scarcity per se were also likely to be important in determining the likelihood of conflict, however violence was found to be most strongly determined by political attitudes.

Contaminant pathways

This section discusses potential contaminant pathways and ultimate human exposure and the implications for feedbacks to poverty and economic growth. Modern environmental health hazards are likely to emerge as critical contributors to the African continents disease burden due to an increasing occurrence of harmful substances in environmental media and consumer products. Nweke & Sanders (2009) reviewed the growing significance of a number of key hazards including mercury, lead, pesticides, water contaminants, domestic and hazardous waste and consumer products (e.g. lead in paint, asbestos cement roofing, food, drinks and traditional medicines). Understanding why these environmental hazards are increasing, the influence of contaminant sources (point and diffuse) and land use (agriculture, forestry, settlement) (Shayo et al., 2011), their contaminant pathways and the role that socio-economic environments and institutional infrastructure play in enhancing human exposure and impacts on wellbeing is discussed using the examples of mining and industrial activities (to represent a source of environmental degradation) and contamination of rivers, lakes and coastal systems to represent a receptor of pollution causing a variety of environmental degradation and subsequent human well-being impacts.

Mining – Large scale (industrial) mining activities as well as Artisanal and small-scale mining activities (ASM) occur across much of sub-Saharan Africa. The latter involves low tech, labour intensive mineral processing and excavation activity, is an economic mainstay in rural sub-Saharan Africa, providing direct employment to over two million people. During the

1990s the perception of ASM began to change with reports of the sector's rapid expansion and employment of vulnerable people including women and children and associated hardships of the employed; not the 'get rich quick' entrepreneurs previously associated with the activity (Hilson, 2009). The majority of Africa's artisanal miners are employed at operations engaged in the extraction of gold but there are also significant 'pockets' of people working deposits of alluvial gemstones and diamonds in countries such as Sierra Leone, Madagascar and The Democratic Republic of Congo (Hilson, 2009).

Efforts are underway to reform large-scale mining activities which are primarily driven by government efforts to attract foreign investments to prospect and mine for gold; legislation that makes it easier for foreign companies to mine in African countries (e.g. low royalty payments, waived duties on imported equipment etc…) have led to a significant amount of land being taken out of the hands of indigenous people, depriving them of economic opportunities. The hold that large-scale miners have over land rights has often caused significant agitation between large scale mine operation management and encroaching artisanal miners, with donors often underestimating the challenge in formalizing and supporting artisanal operators often due to difficulties in ensuring fair payment of mined goods to these groups (Hilson, 2009).

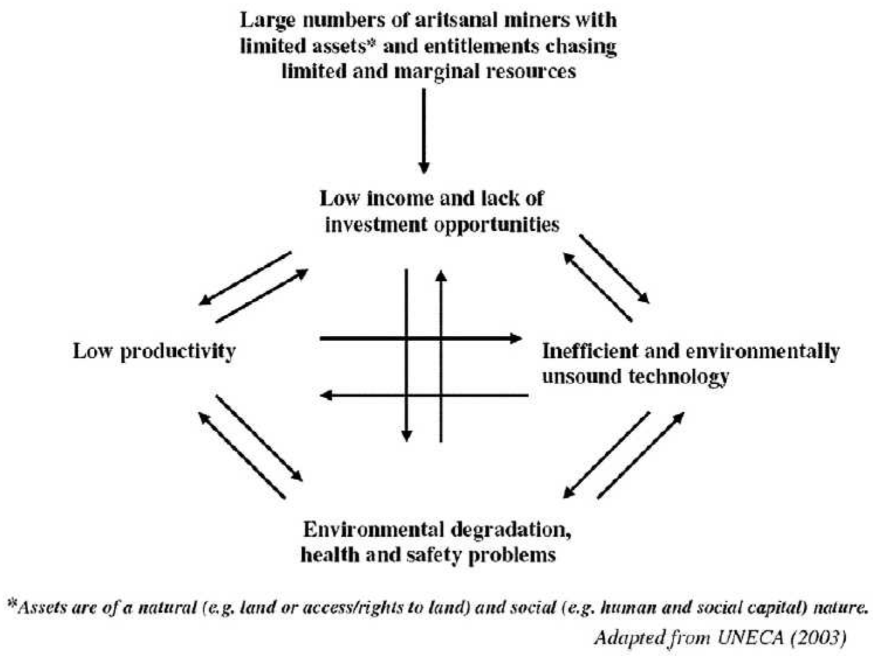
There is much debate as to why people move into ASM. One narrative which continues to wield significant influence in donor circles, despite applying to a minority of situations, maintains that the sector is comprised of 'rush-type' activities: that ASM in sub-Saharan Africa is chaotic and entrepreneurial-driven. This view is couched in the 'demand-pull' school of livelihood diversification—that people are subsisting adequately from farming but choose to 'branch out' because they believe diversified income portfolios will bring them greater economic returns—and has largely been informed by accounts of 'rush-type' diamond mining activities in the likes of Sierra Leone and the Democratic Republic of Congo. Other drivers are thought to be more in the 'distress-push' type school, the idea that people are 'branching out' into ASM because they face precarious financial situations, and are desperate to escape poverty (Hilson, 2009).

Mining activities also cause human health risks (Stuckler et al., 2011) and environmental degradation (Glaister & Mudd, 2010). Health risks associated with mining include tuberculosis due to poor ventilation and high levels of silica dust in the mines, but also increases in the risk of HIV transmission as sex work remains common around all male hostels (Stuckler et al., 2011). ASM often uses rudimentary practices of mineral extraction with the use of mercury for amalgamation being currently the most common means of extracting gold and leading to ASM being the world's largest source of mercury pollution due to intentional uses (Spiegel, 2009). United Nations agencies have stressed that environmental challenges from ASM should be a focus of governments but these advocacies have placed mining issues in a complex socio-environmental planning conundrum. Narrow anti-mercury discourses tend to be generic and globally oriented rather than contextually focused in particular regions; and while banning mercury trade and banning mercury use has featured as a prominent global advocacy to put pressure on miners to stop using mercury, often the advocacies give little if any attention to the local dynamics of mining communities themselves, their technological capacities or their production processes. Socioeconomic complexities in ASM communities frequently remain overlooked by foreign "experts", and meanwhile, evidence in numerous countries strongly suggests that miners' reliance on mercury remains poorly addressed by policymakers as pollution levels have increased in recent years. A range of other heavy metal contaminants including aluminium, iron, arsenic, lead copper, chromium, nickel, manganese, cobalt and zinc have also been associated with gold mining activities e.g. in the Pra river basin in southwestern Ghana (Donkor et al., 2005).

The connections between mining companies and local communities are also often strained. For example Ghanaian mining communities held companies responsible for a series of economic, social, and environmental changes. While recognizing some of the benefits brought by the mines, communities felt that the companies did not live up to their responsibility to support local development. Companies responded by denying, dismissing concerns, or shifting blame (Garvin et al., 2009). Corporate Social Responsibility (CSR) may be one answer to improve company-community relations though some findings show that companies tend to work with concepts of process, disregarding some of the structural features of company-community engagements over time (Luning, 2012).

Finally, the paper by Hilson (2009) reviews the recent literature on poverty traps, where poor health, weak social capital and limited access to investment and resource opportunities are inter-related (see Figure 7; cf. Spiegel, 2009) in relation to ASM which often results from miners being indebted and consequently bound to various middlemen who in the absence of formal support, exploit there advantageous position and provide loans on inequitable terms. The exact dynamics leading to these poverty-traps (who are trapped, why are they trapped and what is the role of institutional and legal frameworks in exacerbating the problem) need to be far better understood before designing and implementing regulations and industry support schemes.

Figure 7 Artisanal mining 'poverty-environment trap'. From (Spiegel, 2009).



Spiegel, (2009) makes the case for combined training on improved technologies and environmental risk mitigation with efforts to empower miners by enhancing access to microfinance services and fairer gold marketing arrangements using case studies from Mozambique and Tanzania. These case studies demonstrate adaptive ways of engaging local concerns in mining areas, highlighting lessons that are especially urgent now that recent policy commitments from Europe and the United States to ban mercury exports have specifically sought to make mercury more expensive for African mining communities. Ultimately, the analysis suggests how regionally focused ecological economics research has a vital role to play in (a) revealing how narrowly conceived responses to pollution can yield counterproductive results as well as exacerbate exploitative labour conditions in low income contexts; and (b) stimulating analytic focus on innovative ways of integrating pollution reduction strategy with grassroots socioeconomic empowerment strategies.

Industrial activities - Some industries can be identified as particularly heavy polluters. Six sectors in particular comprise a substantial fraction of the total industrial discharge in Africa and Asia: pulp/paper, food, chemicals, textiles, tanning and mining (Mollinga & Bogardi, 2011). The situation in Pakistan provides a good example of many developing countries with industrial pollution increasing at a rapid pace and having a significant impact on human health and productivity; this is exacerbated since most industries are located around major cities leading to increases in pollution of streams, rivers and the Arabian Sea with untreated toxic waste (Mollinga & Bogardi, 2011). Other small-scale industries characterise the 'take-off' process in fast growing developing country economies, e.g. in Ghana such industries provided 70% of the total employment in urban areas in 1973 (Mollinga & Bogardi, 2011).

Tanneries – A global review of wastewater and health by Mollinga & Bogardi (2011) identified tanneries as a good illustration of the links between water pollution and its influence on human health. Tanneries use about 30–50 m^3 of water for processing a ton of hide/skin. Water is needed to process raw leather with various chemicals such as lime, sodium carbonate, sodium bi-carbonate, common salt, sodium sulphate, chrome sulphate, fat liquors, vegetable oils and dyes. Because of the water intensive nature of this process, these industries are clustered along rivers into which they discharge toxic pollutants. Tannery waste has a strong colour (reddish to dull brown), a high biological oxygen demand, a high pH and a high dissolved solid content. These pollutants have a devastating impact on ecosystems and subsequently on human health. For example, nitrogen in drinking water can cause blue baby syndrome, reduce ecological biodiversity and reduce blood oxygen transfer that can eventually destroy the tissues of the respiratory system. Intake of high concentrations of germanium (0.015–0.033 mg/m^3) can cause nose bleeding, voice loss, shrinkage of nose membranes and even lung cancer. These studies have identified the risks, though there is no clarity on how much tannery effluent was mixed with other biological and chemical pollutants in other wastewater. This makes it difficult to clearly identify the source of pollutants.

Oil pollution – this is perhaps the most significant cause of water pollution in the Niger Delta region in southern Nigeria; this area being the major oil-producing region of sub-Saharan Africa. The environment of this area has been substantially altered in the last 40 years by the oil industry boom; 95% of the former rainforest has disappeared, over 5800 km of oil pipelines have been built through the Delta since 1958 many of which have repeatedly broken causing catastrophic oil spillages (cf. Luiselli et al., 2006). The water bodies of the riverine Niger Delta region are directly impacted by exploration and production activities. These include dumping of drill mud and oil soaked wastes, oil spillages and gas flaring that result in acid rain. These contaminate the water bodies and result in decline in the availability of quality water. Polluted water sources in the region flow into other water bodies, pollute them and further reduce the quantity of water fit for human consumption and use (Adedeji & Ako, 2009) as well as ecology of the riverine systems where terrapins (Luiselli et al., 2006) and turtles (Luiselli et al., 2006) have been affected by oil pollution. Similar effects of oil pollution can be found in other regions of Africa e.g. the Gabon wetlands where oil pollution in wetland systems was found to affect aquatic macro-invertebrate assemblages (Dinger et al., 2008) and the Atlantic coast of Cameroon (Alemagi, 2007).

Agriculture – this activity has also been a source of water pollution that has often coincided with the emergence of government policies that promote accelerated food production. This has increased the use of fertilizers, herbicides and pesticides that contribute to water pollution. For instance, nitrates, phosphates and other plant nutrients which come from fertilized farm lands encourage the growth of algae and phyto- plankton in water bodies. These become a menace to water bodies as their decomposition drastically cuts down the amount of dissolved oxygen in water resulting in the deaths of aquatic animals and consequently, water pollution. These chemicals are also sprayed directly into the water bodies to catch fish. Sediment pollution of water bodies, as a result of accelerated soil erosion is also a serious and widespread problem. For example, Nigeria is particularly threatened by agriculture derived pollution in the Northern States; soil erosion is a particular problem in the South Eastern States where agricultural practice leaves the soil bare at the start of the rainy season (Adedeji & Ako, 2009).

Attempts to treat the industrial discharge resulting from these various industries often fails; the 'end-of-pipe' treatment approach, poor enforcement of environment protection rules and the informal nature of these industries make regulation difficult and ultimately confound efforts to break the vicious cycle that links wealth creation with waste production.

Rivers, lakes and coastal waters – Pollution of rivers, lakes and coastal waters are arising from a mix of activities including agriculture, industry, and municipal effluents (Oguttu et al., 2008; Bouvy et al. 2008). These activities result in a variety of different types of pollution. Industrial by-products are often discharged as untreated wastes and effluents directly into rivers, estuaries, lagoon or the sea (Adedeji & Ako, 2009).

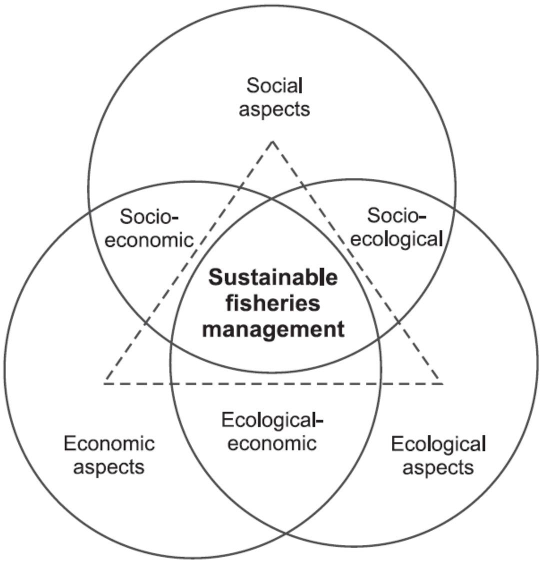
A number of studies have investigated Lake Victoria, Africa's largest tropical freshwater lake which is a crucial ecosystem for over 25 million people in Kenya, Uganda, Tanzania, Rwanda and Burundi who live in the basin and for the greater Nile river system downstream of the lake. Ecosystem management in Lake Victoria has been highly extractive for most of the last 60 years, with the 1990s seeing a period of marked decline in food production, economic contraction, rising poverty, increased burden of human disease and more frequent floods (Swallow et al., 2009). The lake is also being affected by wastes from food processing, textile, leather, paper production and metallurgical industries leading to enhanced eutrophication and bioaccumulation of heavy metals (Oguttu et al., 2008). A recent study by Awange & Obera (2007) has even found that motor vehicle washing and urban run-off points is increasing the pH and phosphate content of wastes entering Lake Victoria. Eutrophication of Lake Victoria is causing related problems of species extinctions and invasive species and severe erosion within the catchment has increased sediment deposition in waterways. There is evidence that these combined stresses are causing poverty-environment traps with some households and areas caught in vicious cycles of low income, low investment in soil management, declines in soil fertility and soil loss while other households and areas are able to achieve higher incomes and investment, maintain soil fertility and conserve soil on their farms (Swallow et al., 2009).

Export of nutrients by rivers to coastal waters of Africa is also a threat to eutrophication of these systems. Yasin et al. (2010) estimated that between 1970 and 2000 the total nutrient export by African rivers increased by 10 to 80%. Such export of wastes can have profound influences on coastal aquifiers and ground water reserves (Re et al., 2011). For example, in the region of Daka, Senegal, approximately 80% of water resources come from ground water reservoirs which are increasingly being affected by a combination of anthropogenic waste effluent mixing with seawater (Re et al., 2011). Similarly, the Kalahari region of southern Africa has high potential for nitrogen input into its groundwater resulting in common occurrences of high nitrate concentrations (Stadler et al., 2012). Identifying the sources of such pollution is essential to develop and implement long-term plans for water resource management for groundwater reserves and urban coastal aquifers.

Effects of water borne pollution are also seen on river and coastal ecosystems with implications for livelihoods through impacts on enterprises such as small scale fishing. Studies have investigated the effect of anthropogenic industrial pollution and sewage on rivers (Beyene et al., 2009) in Ethiopia finding the ecological integrity of 3 major rivers to be affected with losses in macro-invertebrate species. Anthropogenic sewage alone was investigated in relation to forest mangroves in Kenya (Bartolini et al., 2011) and Mozambique (Penha-Lopes et al., 2011). It had been thought that these ecosystem might be pre-adapted to the impact of organic waste discharge making them possible natural waste-water treatment wetlands however, studies now suggest that effluent compromises ecosystem functioning with effects seen on reduced sediment processing by fiddler crabs in Kenya and increased parasitation on shrimp in mangroves located closer to peri-urban centres. A number of studies highlight the need to assess and account for socio-economic, ecological-economic and socio-ecological interaction in sustainable fisheries management systems. For example, Ahmed et al., (2013) studied small scale fishing in the Old Brahmaputra River in Bangladesh and found that livelihoods of fishers are vulnerable owing to declining catches resulting from overfishing, use of destructive fishing gears, environmental degradation, human encroachment, rapid urbanization, water pollution and siltation. Moreover, growing populations within fishing communities have increased fishing pressure which is threatening current income levels. Fishers are vulnerable to over-exploitation of the resource resulting in the loss of social, economic and ecological benefits that can be obtained from responsible fisheries exploiting common-pool resources.

Ahmed et al., (2013) found that to implement a sustainable fisheries management system, the interacting social, economic and ecological aspects must be taken into consideration (see Figure 8). Therefore, any effective management strategies must jointly control over-exploitation of the resource, protect the river ecosystem and conserve fisheries biodiversity. Hence, a combination of socio-ecological, ecological-economic and socio-economic approaches to fisheries assessment and governance must be included in management strategies. In addition to effective implementation and enforcement of legal instruments and strong institutional collaboration, active community participation in the management of the resource base will be crucial in ensuring the long-term sustainable use of fisheries resources.

Figure 8 A conceptual framework for sustainable fisheries management highlighting the need to assess and account for socio-economic, ecological-economic and socio-ecological interaction in sustainable fisheries management systems.



Finally, a number of studies call for the need for a more integrated pan-national approach to management of water resources in relation to groundwater, rivers, lakes and coastal regions. For groundwater, it is deemed important to establish a common African view on the appropriateness of other nations' ground water quality issues for African issues, economic conditions and community circumstances (Kreamer & Usher, 2010). The identification of hydrogeological regions that would benefit from transboundary aquifer management will be important to identify those in need of cross-border co-operation and management (Davies et al., 2012). Some initiatives already exist for management of marine transboundary pollution, e.g. a Strategic Action Programme intended for implementation by the interim Guinea Current Commission to protect the Guinea Current Large Marine Ecosystem which extends from Guinea Bissau to Angola (covering sixteen countries in West and Central Africa) (Ukwe & Ibe, 2010). This initiative intends to adopt a holistic multi-sectoral and regional approach to transboundary pollution management of problems including deterioration in water quality (chronic and catastrophic) from land and sea-based activities especially industrial, agricultural, urban and domestic sewage run-off and mining activities (including the oil and gas sector), eutrophication and harmful algal blooms.

Importantly, there is a need for co-ordination between land and water management (Nkonya et al., 2011) and recent studies suggest that the institutional frameworks necessary to enable such management constructs are indeed being established (Hagos et al., 2011). However, enforcement of desirable management options is problematic and often relies on 'command and control' type policies rather than institutional learning of benefits and incentive-based policies.

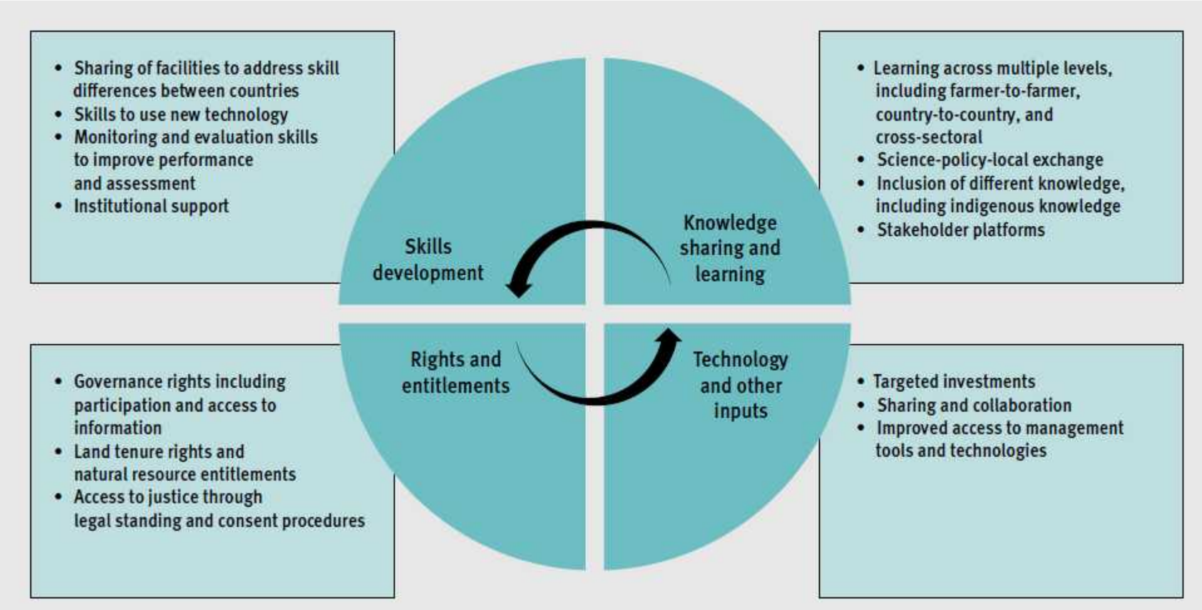
Research gaps

The following list identifies broad generic areas that should be prioritised to understand the drivers, bio-physical – socio-economic inter-connections and dynamics of the relationship between pollution induced environmental degradation and human well-being and poverty. These might be suitable areas for which DFID could offer support to ensure that future environmental policy targeting pollution and environmental degradation would achieve maximum benefit whilst also ensure the building of capacities in environmental management in the region and allowing the monitoring and evaluation of the success of a range of interventions.

- **Need for an understanding of what drives the pollution induced *environmental degradation-poverty* nexus** – traditional viewpoints that poverty was a major cause of environmental degradation are now seen as being far too simplistic. Additionally a range of variables are recognised as dynamically influencing the extent, longevity and societal sectors affected by pollution induced environmental degradation and human well-being. These are likely to vary by pollution type, geographical location and cultural heritage. They are also likely to change rather rapidly with time as developing economies mature and the effects of globalisation continue to determine socio-economic activities. A full understanding of these drivers would seem essential to be able to predict future threats from pollution and environmental degradation, as well as to develop policies to mitigate or adapt to these threats. For example, there is a need to know how financial liberalization, legal institutions and local and national governance, domestic and foreign markets combine as the drivers of pollution induced environmental degradation.
- **Need for an improved understanding of the multi-dimensional interactions between the pollution induced *environmental degradation-poverty* nexus** – although many studies exist for sub-Saharan Africa and South and South East Asia that describe various types of pollution and its influence on environmental degradation there is a tendency for these to focus on either bio-physical aspects *OR* the socio-economic factors that influence human well-being outcomes; studies that investigate the full 'system' are rather limited. This is perhaps due to data availability and the need for multi-discipline research but the connections of pollution through to poverty can only be truly understood with the availability of such studies. To help improve our understanding of the poverty-environmental degradation nexus investigative studies should be specifically addressing particular natural resources and their connections with poverty alleviation simultaneously. The tendency to generalise across all resource sectors only contributes to the complexity of the subject. Instead socio-ecological studies should focus on i. the users of the natural resource (including behavioural characteristics of each user group as well as their interactions with each other and the natural resource base); ii. the impacts of resource degradation across the user groups and their reactions (adaptation/coping mechanism/management solutions) to these changes; and iii. the dynamics of the natural resource itself.
- **Need for capacity building to provide local communities/national and regional organisations with the tools, expertise and knowledge to understand connections within the nexus and develop appropriate behavioural and policy responses. -** Environmental policy is often out of step with realities on the ground, with governments acting alone often unable to effect the necessary change. Innovative institutional arrangements for pooling financial resources, knowledge and capacity, can help to achieve environmental goals. Improving capacity and equity among diverse communities, including governments, is essential to support collaboration and to secure rights, all of which can help to reduce the effects of pollution on environmental

degradation. The policy options shown in Figure 9 demonstrate the potential of various strategies to enhance capacity (UNEP, 2012).

Figure 9 Selected strategies from various policy options for strengthening key components of capacity in Africa (cf. UNEP, 2012).



- **Need for an improved understanding of the potential solutions to pollution induced environmental degradation problems, ideally with an assessment of their multiple benefits (or trade-offs)** – poverty is influenced by an extremely wide range of interacting factors which can often have consequential effects to other areas of human-wellbeing as well as suffering positive feedback loops and traps. Identifying these connections and feedbacks can help identify policy interventions that can intervene at the optimum point in the cycle to ensure it breaks. Optimal solutions are likely to be those that address a number of factors related to both poverty and environmental degradation in a mutually beneficial manner. Developing methodologies to allow more holistic cost-benefit assessments of pollution damage and remediation to be performed will provide decision makers with improved knowledge to allow more informed policy interventions.
- **Need for improved data availability and suitably robust and resource efficient monitoring methods for use in understanding the links between pollution, environmental degradation and poverty** - databases describing physical, social and economic data in a consistent spatial and temporal dimension are extremely limited in many parts of Asia and sub-Saharan Africa. These are essential for any robust investigative study into the causes and consequences of pollution induced environmental degradation. Simple methods of pollution monitoring should be investigated and trialled whilst ensuring any data collected is appropriate to understand the influence of environmental degradation on human-well-being within different socio-economic and political settings. Examples of key datasets that are lacking include those describing deforestation (two recent reviews by FAO showed very different trends for 2000-2005 and data to evaluate trends in all water related diseases, currently global data trends on cholera are used as proxy (UNEP, 2012). Datasets that integrate knowledge are also important, for example 'environmental footprints for economic production' at the level of country and product, are required to describe energy and water inputs and key pollution

outputs in order to understand how patterns of production and consumption affect environmental systems.

- **The need for improved governance and appropriate international policy approaches** - to ensure globalisation protects against poverty rather than being a driver of poverty. This will become ever more important as population pressure continues to increase over the next 30 years, especially in low & middle income countries; the concept of a 'double leap' in addressing sustainable development and poverty is urgently required. For example, studies assessing the role international trade plays in shaping the 'Pollution Haven Hypothesis', which suggests that emission reductions observed in developed nations are partly the result of shifting 'dirty' production to developing nations with lax environmental standards are useful to better understand the role of globalisation as a driver of pollution and environmental degradation. The benefit of countries working together, for example, through efforts to manage transboundary pollution of air and waters (marine, fresh- and ground-water), should be prioritised given the additional gains that can be made in reducing pollution through these international collaborations. Further research is needed on PES schemes given that a main limitation to the success of these shcemesschemes is often due to poor governance.
- **The need for improved metrics** - to assess the state and dynamics of pollution impacts on natural resources in relation to the environmental degradation-poverty nexus. Is the macro- economic approach of the Environmental Kuznets Curve really helpful in understanding local scale, societal differences in links between environmental degradation and poverty or other metrics required to assess the current state and future trends?

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