

Climate Change as a Wicked Problem: An Evaluation of the Institutional Context for Rural Water Management in Ghana

SAGE Open
April-June 2012: 1–14
© The Author(s) 2012
DOI: 10.1177/2158244012448487
<http://sgo.sagepub.com>


John FitzGibbon¹ and Kenneth O. Mensah¹

Abstract

Understanding complexity suggests that some problems are more complex than others and defy conventional solutions. These wicked problems will not be solved by the same tools and processes that are complicit in creating them. Neither will they be resolved by approaches short on explicating the complex interconnections of the multiple causes, consequences, and cross-scale actors of the problem. Climate change is one such wicked problem confronting water management in Ghana with a dilemma. The physical consequences of climate change on Ghana's water resources are progressively worsening. At the same time, existing institutional arrangements demonstrate weak capacities to tackle climate change–related complexities in water management. Therefore, it warrants a dynamic approach imbued with complex and adaptive systems thinking, which also capitalizes on instrumental gains from prior existing institutions. Adaptive Co-Management offers such an opportunity for Ghana to adapt its water management system to climate change.

Keywords

climate change, wicked problems, institutions, rural water management, Adaptive Co-Management

Introduction

The concept of “wicked problem” is embedded with notions of complexity. In planning and management policy, the term *wicked problem* is used to refer to adverse social and environmental situations that overwhelm existing practices and persist even after the application of best-known practices (Ludwig, 2001; Ritchey, 2005–2011; Rittel & Webber, 1973). The concept is applied in organizational decision making as a “force of fragmentation” whereby stakeholders polarize around their views of a problem, thereby undermining collaborative problem solving (Conklin, 2001). From an interventionist perspective, “a do-nothing” approach is perhaps a reasonable option for a problem that defies best intervention practices. However, Brown, Harris, and Russell (2010) pointed out that wicked problems will not be solved by the same tools and processes that have created them. This suggests that action is incumbent, but action must implore mechanisms and paths different from those that have perpetuated the problem in the first place.

In Ghana, climate change is an emerging issue in the national discourse. Already it is known to present challenges to current development efforts and environmental management capacities. This article examines the nature of climate change as a wicked problem in water resource management in Ghana, and how social and institutional capacities influence an understanding of climate change and efforts to

address the dilemma. Using rural water management as a reference point, this article argues that climate change as a wicked problem in Ghana can be demonstrated in two ways: (a) its sheer physical consequences on water resources and (b) weaknesses in institutional capacity to adapt. But, instead of a fatalist approach, appropriate social and ecological institutional capacities can be developed for effective adaptation. We propose adaptive co-management (ACM) as a useful institutional approach.

Complexity, Wicked Problems, and Climate Change

Complexity implies degree of difficulty in defining causal linkages of an event as well as determining the boundaries of their effects to allow for management of them with any meaningful degree of accuracy and confidence. Complexity is determined by the degree of uncertainty and social disagreement on a particular issue (Patton, 2011; Stacy, 1996; Zimmerman, 2001). A problem at the far end of an uncertainty

¹University of Guelph, Ontario, Canada

Corresponding Author:

Kenneth O. Mensah, School of Environmental Design and Rural Development, University of Guelph, 50 Stone Rd. East, Guelph, Ontario, N1G 2W1, Canada
Email: mensahk@uoguelph.ca

and disagreement continuum is considered complex because it challenges existing capacities to predict outcomes and solutions, and therefore heightens disagreement resulting in stakeholder conflicts. Complexity can be judged by source and nature. When a problem is generated by multiple factors from multiple sources, it is difficult to target the linkages of the causal factors and therefore raises questions of complexity to the extent that identification of the problem, and hence its solution, becomes difficult. Complexity can also be of a technical and social nature. The technical side relates to limitations of quality of information and deficiency in existing knowledge systems that make diagnosis of a particular situation problematic because of high degree of uncertainties in the solutions offered. The social aspect focuses on inherent difficulties in coordination of activities, information, and stakeholders across disciplines, sectors, and scales in a manner that minimizes conflicts and builds consensus around solutions for a situation (Patton, 2011).

The term *wicked problems* was originally coined by Rittel and Weber (1973) as the opposite of “tame problems,” where the latter can be resolved with traditional methods because it is easy to define cause-and-effect relationship of the problem as well as the solutions. Conversely, wicked problems are social planning problems that defy traditional methods because they are “ill-defined, ambiguous and associated with strong moral, political and professional issues” (Ritchey, 2005-2011, p. 1). They are complex, with linkages to other issues evolving in a dynamic social context, and tackling one often leads to unintended consequences of generating new sets of wicked problems. They are strongly stakeholder dependent, often with little consensus about what the problem is, let alone how to resolve it (Ritchey, 2005-2008, p. 1; Rittel & Weber, 1973). Thus, complexity and wicked problems are interconnected. Wicked problems are inherently complex in their scale of uncertainty and disagreement, as well as in their technical and social nature; therefore, they are best tackled by interdisciplinary approaches, coexistence of different knowledge systems, flexible governance, and participatory processes and practices that allow for adaptive learning and ethics.

The concept of wicked problems has been applied in complex and adaptive systems thinking to draw linkages within social and ecological systems (SES). SES are difficult to manage both at the technical and social levels because often they involve multiple sources, multiple actors, and their externalities jump scales for which cross-scale institutions are required. According to Walker et al. (2002),

A fundamental difficulty in managing SES for long term, sustainable outcomes is that their great complexity makes it difficult to forecast the future in any meaningful way. Not only are forecasts uncertain, the usual statistical approaches will likely underestimate the uncertainties. That is, even the uncertainties are uncertain. (p. 2)

Contributing factors to uncertainty include dynamism of the drivers of change such as human behavior, ecological factors, and scale of interaction of the processes (Dolšák et al., 2003; Gunderson & Holling, 2002). The dynamism factor is particularly informative for climate change adaptation because it denotes transition of a system where internal and external variables create constant changes in the social or ecological domains, and a change in the critical variables of one domain requires institutional adjustments in the other to prevent collapse of the entire system (Gunderson & Holling, 2002).

It is within this context that the interconnections among complexity, wicked problems, and climate change can be vividly drawn, in that climate change adaptation requires restructuring social and ecological institutions to adjust to rapid and uncertain change as well as to take advantage of the opportunities presented by such changes (Brown et al., 2010). For instance, Ludwig (2001) following Rittel and Weber’s definition described climate change as one example of wicked problems noting, “Such problems have no definitive formulation, no stopping rule, and no test for a solution. There will likely never be a final resolution of any of them. Each such problem is unique: They defy classification” (p. 3). The author identified terminologies used to describe wicked problems in the ecological literature including *truly complex*, *complex all the way down*, and *postnormal*, characterized by *radical uncertainty* and *plurality of legitimate perspectives*. Thus, climate change is intractable, and adaptation solutions are elusive, making climate change a perfect fit for the complexity and wicked problems model.

Indeed, current global discourses suggest that no single phenomenon exhibits the characteristics of wicked problems like climate change. It attracts varying interests and perspectives constantly juggling for recognition and acceptance. For instance, the Australian Public Service Commission on Climate Change demonstrates two perspectives. First are climate change believers, but acknowledge global structural inequalities among nations and refer rich nations to the Kyoto Protocol to mitigate their greenhouse gas emissions. Kyoto urges that remedying climate change would require all governments to formally agree on future emissions cuts and the mechanisms to achieve the set targets. The onus is on developed countries to mitigate their emissions and also provide developing countries with financial and technological assistance (Ayers & Dodman, 2010; Flamos & Begg, 2010; United Nation Framework Conventions on Climate Change [UNFCCC], 1998). This position is frequently contested among UNFCCC parties. The second is the skeptical perspective that questions the authenticity of climate change as a human-induced problem. They argue that in a worse-case scenario, the catastrophic consequences of climate change will be moderated by technology and market forces. This could lose traction as skepticism about climate change wanes. A third view may be added, focusing on governance reforms with emphasis on participation, ethics, and justice with decision making devolved to local levels where citizens’ involvement is instrumental (Both ENDS, 2007; Brown et al., 2010).

These divergent views demonstrate a high degree of disagreement on the fundamental causes of and solutions for climate change, as well as a high degree of uncertainty about our understanding of all the variables involved in climate change processes. In addition, it points to the deficiency in our technical and social capabilities to be able to deal with a phenomenon with multiple sources, actors, stakeholders, cross-scale influences (externalities), and linkages (Australian Public Service Commission, 2007). This leaves the policy maker with a dynamic, plural, and argumentative system of policy definition—typical of many wicked policy problems—and also leaves the policy maker with a problem in which complexity outweighs the capabilities of his or her current repertoire of methodologies (Australian Public Service Commission, 2007). It echoes Hamilton's (1999) point that "the problem of climate change is intractable by our traditional scientific methods" (quoted in Ludwig, 2001, p. 757). The futility of relying on those same tools and practices that have augmented the creation of the climate change problem is being noted (Brown et al., 2010).

Current adaptation frameworks are not sophisticated enough to sufficiently integrate the biophysical and the sociopolitical issues across multiple scales (Brown et al., 2010; Intergovernmental Panel on Climate Change [IPCC], 2007; United Nations Framework Conventions on Climate Change [UNFCCC], 2006). Yet, consensus coalesce around the notion that effective and practical adaptive management of climate change depends on understanding the scale of influences of the drivers of change (general and systemic, slow and fast) at work in the system (Pahl-Wostl, 2007; Tschaket & Dietrich, 2010). As Wilbanks (1999) noted,

At least, it is clear that some of the driving forces operate at a global scale while many of the phenomena that underlie environmental processes operate at a local scale. Understanding climate change processes and responses require attention to multiple scales and how they relate to one another. (p. 602)

The Australian Public Service Commission is apt in its observation that the practical challenges facing our capabilities to address climate change are often philosophical (ideological) and methodological, particularly as they relate to cross-scale linkages, trust and social capital formation among institutions, governance reforms that encourage participation, equity and global justice, and creating spaces for social learning in an adaptive manner. In addition, there is consensus that effects of climate change are so advanced that mitigation alone is too late to make any meaningful reversals to the damage already in motion, hence the focus on adaptation (Lambrou & Piana, 2006).

Method

Our approach is diagnostic and prescriptive with a qualitative analytical slant. We used primary and secondary data

sources. Primary data came from interviews with 18 key informants from government, research, and civil society organizations whose work intersects with water resource management and environmental protection. Participants responded to questions focused on the challenges of climate change in the water sector and the capacities of water institutions to adapt. Responses were then triangulated with secondary sources including published government, research, and newspaper reports for reliability and validity. For analysis, we examined the extent to which the data matched up to Rittel and Webber's (1973) construct of wicked problems. Based on the findings, we suggest a method with a greater capacity to handle complexity (i.e., climate change).

Climate Change Trends in Africa

In a certain ironic fashion, Africa, the smallest contributor to greenhouse gas emissions, is expected to be one of the most vulnerable to the impacts of climate change (Ayers & Dodman, 2010; IPCC, 2007; Magadza, 2000; UNFCCC, 2006). Projections of multiple stresses, such as increasing severity and frequency in water shortages, declining agricultural productivity, desert and coastal encroachments, as well as low adaptive capacity, raise concerns of security, livelihoods, mass emigration, and development on the continent (Brown & Crawford, 2008; Sharma et al., 1996; UNFCCC, 2006). By 2020, it is expected that more than 250 million Africans would be exposed to increased water stress, lacking access to portable water or adequate sanitation because of climate change, resulting also in 50% reduction in rain-fed agricultural yields (IPCC, 2007). This is against the backdrop promise of universal access to safe and reliable water supply by the UN Water Decade (1980-1990).

It is believed that climate change has affected rainfall regimes resulting in the commonly observed frequency and severity of floods and drought on the continent (IPCC, 2001; Leroux, 2001). In Africa, coastal area sea-level rise is expected to result in annual flooding and salinization of water sources, which will severely affect millions of people in low-lying areas (Bunce, Rosendo, & Brown, 2010; McGranahan, Balk, & Anderson, 2007). The cost of adaptation could amount to at least 5% to 10% of GDP (IPCC, 2007). This is a hindrance to the realization of key millennium development goals such as poverty reduction and ensuring environmental sustainability (Ayers & Dodman, 2010; Both ENDS, 2007; UNFCCC, 2006). Not surprising, IPCC (2007) identified water security among key potential impacts of climate change in Africa, as well as concerns of low adaptive capacity on the continent. Africa's low adaptive capacity revolves around its capital base required for capacity building and sustainable development policy because vulnerability to climate change depends on development indicators (Ayers & Dodman, 2010; Gyampoh, Amisah, Idinoba, & Nkem, 2009; UNFCCC, 2006).

Climate Change as a Wicked Problem in Water Management in Ghana

Ghana is noted to share some notable developmental challenges with other African countries such as reliance on rain-fed agriculture, vulnerability to drought and floods, poor governance, and rapid population growth, which put undue pressure on the capacity of government to provide basic infrastructural services (Brown & Crawford, 2008). Climate change and variability complicate these issues and undermine overall development efforts in Ghana. As a wicked problem in the country's water sector, climate change manifests in two dimensions: first, the physical consequences of climate change on ecological resources (including water); second, climate change confronts existing water institutional arrangements with a dilemma exposing weaknesses in their capacity to tackle complexities associated with water management.

Physical Consequences

Ghana is among countries where climate change is projected to create water stress by 2025. As far as water resources management and use are concerned, three climate change-related issues are relevant: extreme events brought about by changes in rainfall and temperature regimes, variability, and sea-level rise. As Table 1 shows, these climate change issues, in turn, have negative repercussions on (a) the availability and quality of freshwater resources as hitherto perennial water sources dry up because of severe droughts and pollutions of water bodies due to increased floods and salt intrusion; (b) security of human lives, property, and water infrastructure as increased droughts, floods, and storm surges destroy property, water supply, and hydro-generation infrastructure, which result in the displacement of thousands, deaths, service disruption, and social upheavals; (c) poor health conditions and increased risk of contracting water-related diseases; and (d) reproduction of gender inequalities as women's reproductive work and time allocated to complete the tasks increase during changing climatic conditions.

Rainfall-temperature regimes. Historical records across Ghana suggest discernible future temperature increases and rainfall declines. Temperature is estimated to rise on average by 0.6°C, 2.0°C, and 3.9°C by the year 2020, 2050, and 2080, respectively. Rainfall is also predicted to decrease on average by 2.8%, 10.9%, and 18.6% by 2020, 2050, and 2080, respectively, in all agroecological zones. Upper sections of the Volta region and three northern regions suffer drought once in every 3-year cycle (Arku, 1993). Climate change remains an issue for the whole country, but climate variability is a major challenge, especially for rural communities that depend on natural resources and environmental services (van der Geest, 2004). For rural residents without piped water, irregularity and extremes in weather patterns (droughts and floods) directly affect water

availability and access, placing additional stresses on their daily activities. As Gyampoh, Idinoba, and Amisah (2008, p. 10) observe, "Whereas models and records of precipitation mainly focus on changing amounts of precipitation with climate change, knowledge of indigenous people also emphasize changes in the regularity, length, intensity, and timing of precipitation." Brown and Crawford (2008) observe that climate variability in combination with population growth will compound the adverse effects of inadequate water supply in the country, particularly in the dry North, and could lead to a 12-fold increase in the demand for irrigation by 2050. The major dams that have been the mainstay of urban water supply fluctuate in similar fashion to rivers, ponds, and creeks, which serve rural communities in correspondence to climate variability (Gyampoh et al., 2009). The crisis could get worse, especially for rural water systems, if effective adaptation mechanisms are not found soon (Environment Protection Agency [EPA], 2000; Ferguson & Rankin, 2005).

Sea-level rise and coastal challenges. Climate change compounds the adverse effects of inadequate water supply in inland communities. Yet, sea-level change from that in 1990 indicates an average rise of 5.8, 16.5, and 34.5 cm by 2020, 2050, and 2080. An estimated sea-level rise of 1 m by 2100 could inundate 1,120 km² of lands and put 132,000 at risk (EPA, 2000). It will worsen salt water intrusion into estuaries and aquifers, raised coastal water tables, and exacerbate coastal flooding and storm damage to coastal properties (EPA, 2000; Dankelman et al., 2008; Douglas et al., 2008). This will put two thirds of lands and residents living within the East Coast at risk. It will cost an estimated US\$1.14 billion to protect all shorelines at risk with populations greater than 10 persons/km² with seawalls and US\$590 million to protect only the "important areas" (EPA, 2000).

Gender, water, and climate change adaptation. Women have low adaptive capacities arising from ascribed social and economic inequities inherent in traditional and nontraditional structures that manifest in distinct differences of unequal access to property rights, information, education, unemployment, and resources between men and women (Mensah-Kutin, 2008). Changing climatic conditions (e.g., droughts) aggravate these gender relations by increasing women's reproductive work and time allocated to complete water-related tasks (Arku & Arku, 2010; Awumbila & Momsen, 1995). The result is that in comparison with men, most women are less represented in productive activities, are poorer, and participate less in the governance of natural resources, including water (Gyimah & Thompson, 2008; Mensah-Kutin, 2008). Thus, climate change will exacerbate the woes of women and poor people because their livelihoods depend on natural resources and economic sectors that are susceptible to climate change. In this regard, Ghana's climate change policy is criticized for taking a gender-neutral position, thereby worsening the vulnerability of these groups (Mensah-Kutin, 2008; Tutuah-Mensah, 2009).

Table 1. Physical Consequences of Climate Change on the Water Sector in Ghana

Consequences				
Indicators	Scarcity and poor quality of freshwater resources	Security (life and water infrastructure)	Health	Gender
Increasing or intense extreme events, for example, flooding, drought, temperatures, and gusty winds	<p>Drying of hitherto perennial rivers in the dry season that serve as rural water sources, for example, -water shortage in March 2010 and August 2011 attributed to drying up of Dabose and Inchaban rivers that supply water to the twin cities of Sekondi and Takoradi</p> <p>A general reduction in annual river flows in Ghana by 15-20% for the year 2020 and 30-40% for the year 2050</p> <p>A reduction in groundwater recharge of 5-22% for 2020 and 30-40% for 2050</p> <p>An increased irrigation water demand of 40-150% for 2020 and 150-1,200% for 2050</p> <p>By the year 2020, all river basins will be vulnerable, and the whole country will face acute water shortage</p> <p>Pollution of water bodies because of increased flooding, restricting their use and putting further constraint on water availability to meet growing demand</p>	<p>Frequent floods and drought have potential negative impacts on life, properties, and expensive water infrastructures for domestic water supply, irrigation, and hydropower generation, for example,</p> <p>-2007 floods affected about 332,600 people and caused 56 deaths in the Upper East, Upper West, and Northern regions and parts of Western region; polluted unprotected water sources of rural residents</p> <p>-July 2011 flood destroyed lives and property in Eastern and Volta regions; polluted unprotected water sources of rural residents</p> <p>-a 60% reduction in hydropower generation is expected in 2020</p> <p>-2006 drought led to power rationing because of low levels of water in the Akosombo dam</p> <p>-September 2011 angry mob in Tamale besieged VRA offices to protest rampant power outages</p> <p>Dilemmas of managing the north-south divide of water supply; allocating water between energy in the south and agriculture in the north; management of regional water sources</p>	<p>Poor health conditions and increased risk of contracting water-related diseases</p>	<p>Women, children, and poor people negatively impacted the most as -they will have to spend more time traveling longer distances in search of good quality water</p> <p>-their livelihoods depend on natural resources and economic sectors that are susceptible to climate change</p> <p>Women's reproductive work and time allocated to complete the tasks increase during changing climatic conditions, for example, drought.</p> <p>Reproduction of gender inequality as comparatively most women than men will be less represented in productive activities, earn less money, and participate less in governance of water resources</p>
Variability		<p>Unpredictable weather, especially shifting temperature regimes, late start and shorter rainy season, for example, -In northern Ghana, there is two maxima high temperature months (January and March) instead of known single one, previously recorded in March</p> <p>-Previously, the rainy season started in April and ended around late September or early October. Recently, the rainy season started in June or July with extreme heavy rainfall in September to October, resulting in destructive floods or ending abruptly and resulting in drought conditions</p>	<p>Same as above</p>	<p>Same as above</p>
Sea-level rise	<p>Worsening salt water intrusion into estuaries and aquifers, for example,</p> <p>-sea erosion at 3-5 m/year increases seepage into water</p> <p>-high tide increases salt water intrusion into Kesseve Water and Dabose in Dangme East and Western region, respectively</p>	<p>Two thirds of lands and residents living within the East Coast at risk</p> <p>Raised coastal water tables, exacerbating coastal flooding and storm damage to coastal properties</p> <p>It will cost an estimated US\$1.14 billion to protect all shorelines at risk with populations greater than 10 persons/km² with seawalls and US\$590 million to protect only the "important areas"</p>	<p>Increased consumption of saline water because of dwindling alternative sources</p> <p>Forcible choice between unaffordable alternative sources and bad water, for example, -May to June 2009 residents of Ada recorded high rates of heart-related diseases because of consumption of salinized water</p>	<p>Same as above</p>

Note: VRA = Volta River Authority

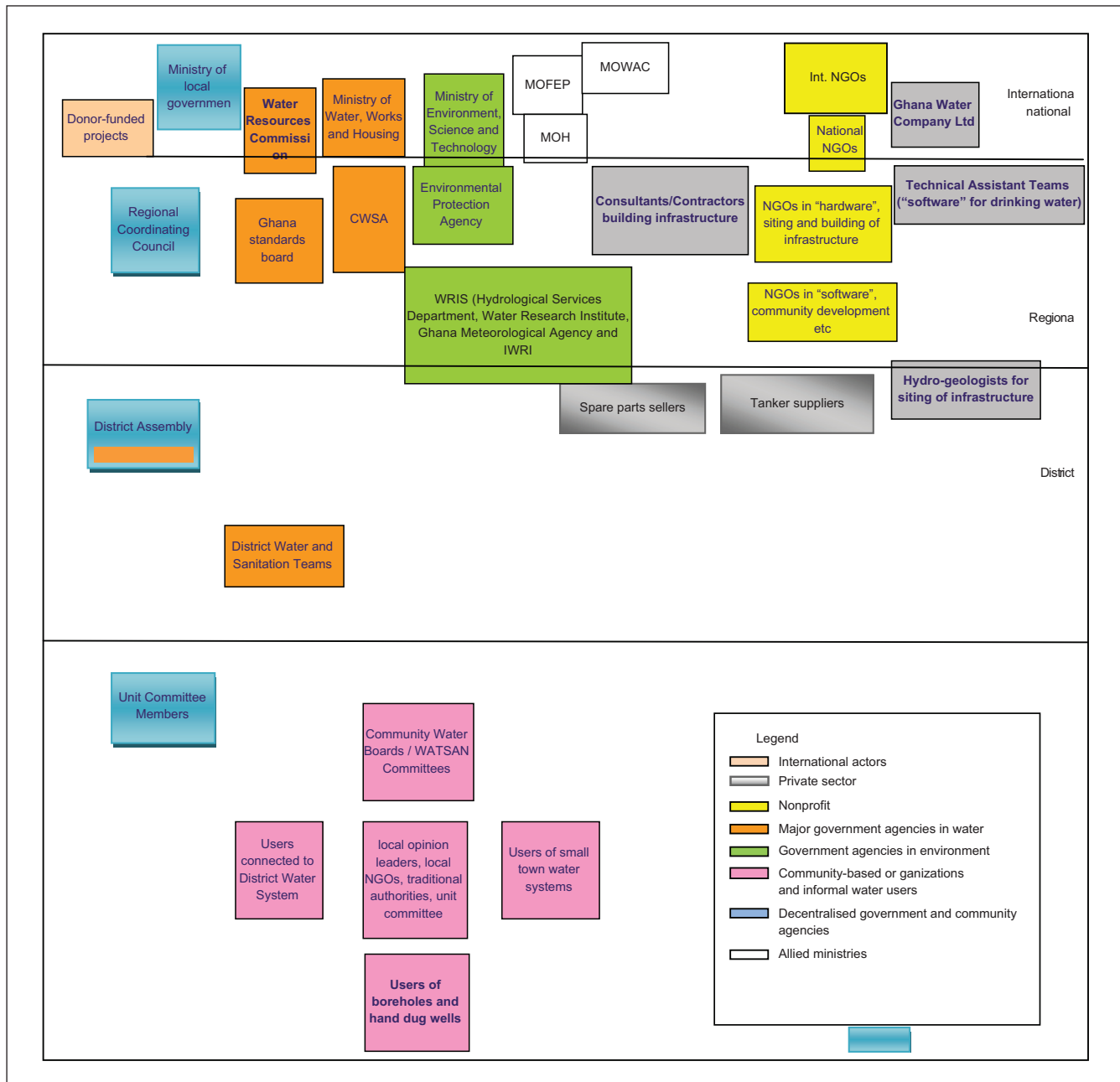


Figure 1. Institutional and stakeholder arrangements in water management and supply

Source: Modified from Birner, Schiffer, Asante, Gyasi, and McCarthy (2005).

Note: CWSA = Community Water and Sanitation Agency; NGO = nongovernmental organization; WRIS = Water Resources Information Services; MOFEP = Ministry of Finance and Economic Planning; MOH = Ministry of Health; MOWAC = Ministry of Women and Children; WATSAN = Water and Sanitation Committees.

Security concerns. Brown and Crawford (2008) identified climate change-related security challenges that Ghana will face, including managing the north-south divide of water supply, allocating water between energy in the south and agriculture in the north, management of regional water sources, and border issues. However, the authors maintain that climate change is just one of the interrelated development issues that

Ghana faces and that, except in extreme scenarios, the effects of climate change may only act as a catalyst to exacerbate a number of existing problems. Worsening negative impacts of frequent floods and drought life and property, and on expensive infrastructures for domestic water supply, irrigation, and hydropower generation in Ghana (Kankam-Yeboah, Amisigo, & Obuobi, 2011), however, suggest that climate change

is a direct security threat. Furthermore, as far as water supply is concerned, there is little doubt that the impact of climate change and variability is both a direct and determining factor in access to potable water. Therefore, social and institutional reforms are needed to address the recalcitrant and complex issues associated with climate change and related water problems.

Social and Institutional Reforms in Ghana

It is axiomatic among risk management practitioners that resource availability and institutional capacities are key determinants of the ease with which climate change-related risks and vulnerabilities deteriorate into full-blown disaster. In this regard, Ghana has undertaken several reform policies to build its social and institutional capacities, resulting in an elaborate political decentralization and water governance structure (Figure 1). Since 1988, Ghana established political and administrative institutions at three levels: district, subdistrict, and community. In addition, it has privatized its water sector and established management, facilitation, and regulation agencies such as the Water Resources Commission (WRC), Community Water and Sanitation Agency (CWSA), Ghana Water Company, among other stakeholder agencies. In particular, CWSA was established in 1998 with the mandate to facilitate water and sanitation facilities delivery and hygiene education to rural communities (Odame-Ababio, 2003). CWSA fosters partnerships with foreign and local public, private, and civil society organizations to streamline their activities in the rural water sector. Current rural water supply coverage by CWSA stands at 63%. The activities of CWSA are supposed to end at the regional level. Responsibility for water supply and capacity building at the district level rests with the District Assembly, which must liaise with subdistrict entities such as Unit Committees, local water and sanitation teams, and related stakeholders. Thus, Ghana's water sector, especially rural water supply, demonstrates a mosaic of inter-linked institutions from international through local-level interspersed with private, nongovernmental organizations (NGOs), and civil organizations (Mensah, 1998; Schiffer, McCarthy, Birner, Waale, & Asante, 2008).

On climate change, Ghana is active at the international level as a party to the UNFCCC and signatory to the Kyoto Protocol. Internally, mainstreaming climate change into existing decentralized system and development policies, such as the Ghana Growth and Poverty Reduction Strategy and millennium development goals, are seen as the surest way to effectively cope (United Nations Development Programme, 2008; Tutuah-Mensah, 2009). The creation of the EPA with the mandate for environmental sustainability is acknowledged as a notable climate change effort. Other responsibilities of EPA include research and development, rule making, standard settings, and enforcement. In addition, it collaborates with other stakeholders to ensure sustainable water resource management (Laube, 2007; Mensah, 1998).

Despite all these initiatives, climate change represents a perplexing phenomenon for Ghana's water management institutions. First, climate change is a relatively new area in the national discourse and policy making, which suggests that the institutional memory, knowledge base, and institutional collaboration required for effective adaptation actions are not only underdeveloped but also not fully understood. In addition, climate change was originally not envisaged in the mandates of major water institutions such as the WRC and CWSA. As such the CWSA has continued to carry out its activities without recourse to climate change, whereas the WRC is only recently making strides with the Climate Change Adaptation Project to make the connections between water resources management and climate change (WRC, 2010). In addition, the nature and scale of the major causes, important stakeholders, and regimes in climate change resolutions operate beyond the national scale, thereby limiting the ability of national institutional actors to adapt. Finally, linkages between some national institutions, such as CWSA and EPA, and international donors and NGOs provide opportunities to access valuable resources to undertake water and/or adaptation projects. However, overdependence on foreign donors to undertake such a crucial national project raises questions of sustainability and security in the water sector. For instance, more than 70% of CWSA operating budget comes from foreign donors.

Table 2 provides a comparative analysis of Ritter and Weber's (1973) characteristics of wicked problems and the extent of their manifestation in climate change vis-à-vis water management in Ghana. It explicates the complex relationship between climate change and water resource management in Ghana because of multiplicity of causal factors, actors and views involved, as well as scale concerns. Institutional reforms (i.e., decentralization and water governance) have the potential to improve our understanding of the relationships between water supply and impacts of climate change. However, the current practices exhibit low adaptive capacities, which result from weak collaborative linkages among institutions, and do not foster the requisite learning to enable rural communities to effectively respond and adapt their water resources to climate change (Mensah, 2012). Ghana, therefore, needs an approach that can reasonably respond to climate change and related complexities in water management.

Responding to Complexity and Uncertainty, That Is, Wicked Problems

Stacy (1996) provided a useful model for responding to complexity, that is, wicked problems (Figure 2). The zone of complexity is between the region of chaos (Zone 4) and the regions amenable to traditional management approaches (Zones 1, 2, and 3). The complexity zone requires ingenuity

Table 2. Properties of Wicked Problems

Rittel and Weber	CC and water supply in Ghana
There is no definitive formulation of a wicked problem	<ul style="list-style-type: none"> i. Disparate knowledge and opinions on whether observed changing weather patterns are CC related or constitutive of the natural cycle, for example, significant knowledge exist in formal institutions (government agencies, NGOs, and research institutes) and educated urban residents about drivers of CC. Most laymen and rural residents are ignorant of drivers of CC or perceive it as an act of God (Gyampoh, Amisah, Idinoba, & Nkem, 2009; Mensah, 2012) ii. As a result of different experiences, perceptions and political interests of these multiple publics, water supply policies, institutions, and infrastructure to adapt to CC seem to be aiming at a moving target
Wicked problems have no stopping rule	<ul style="list-style-type: none"> i. CC and its impacts are progressively getting worse while uncertainty remains about how long it will linger on, for example, past climate records, and future predictions point to progressive deterioration with continuous scarcity and poor quality of freshwater resources ii. Majority of CC programs are donor funded. It is doubtful whether Ghana can self-generate satisfactory criteria and be able to sustain its adaptive capacities over a long uncertain period especially beyond the cycle of donor funding iii. Dire implications for rural communities because their adaptation capacity is threatened by a combination of poverty, disregard for traditional norms, poor education and knowledge flow, and dependence on charity, mainly NGOs
Solutions to wicked problems are not true or false but good or bad	<p>Although the EPA, WRC, CWSA, among other public agencies, are mandated by law, their ability to determine the correctness of any water adaptation decision to implement against CC rarely gets past critical scrutiny or challenge by numerous stakeholder agencies such as NGOs involved in the environment and water sector</p> <p>Because the major drivers of CC operate at the global scale, it is impossible for national and local actors to determine when desired results of a proposed intervention to adapt water systems to CC has been achieved, especially taking into account the inability of any system to fully appraise all unintended consequences prior to or post intervention</p>
There is no immediate and no ultimate test of a solution to a wicked problem	<p>CC-related droughts and floods create water shortages through drying up of local streams and perennial rivers and disrupting water quality. Conventional solutions have resorted to massive dam projects such as Akosombo, Kpong, Densu, and so on. However, these projects have brought irreversible hardships to communities that depend on these rivers for their livelihoods and water needs</p> <p>CC-related water supply resolutions are politically shaped by varying experiences, ideologies, and power of stakeholders from international to local levels. Ghana has no agreement criteria for judging successfully completed water adaptation programs against CC; whether to base judgment on international agencies and government list of funded programs or on dominant agreement among all stakeholders is uncertain</p>
Every solution to a wicked problem is a “one-shot operation” because there is no opportunity to learn by trial and error; every attempt counts significantly	
Wicked problems do not have an enumerable (or exhaustively describable) set of potential solutions, and there is no well-described set of permissible operations that may be incorporated into the plan	
Every wicked problem is essentially unique	<p>By scale and intensity, CC is one of a kind, nothing close to known experiences of extreme environmental events (e.g., droughts or floods) related to water resources in Ghana. Therefore, it makes insufficient or inappropriate adaptive capacities crafted out of knowledge gained from traditional and formal institutional arrangements over the years because of the lack of understanding of the inherent complexities related to multiple causes and scale, and constant trajectory changes. The situation is exacerbated by disjointed collaboration among stakeholder institutions</p>
Every wicked problem can be considered to be a symptom of another problem	<p>The impacts of CC on water resources and supply reflect growing concerns about their interconnections with other intractable national and global problems, for example, an unjust global geopolitics, deteriorating social and ecological systems, poverty, misfit/incapable institutions and resource governance system, gender inequalities, and so on. Therefore, exclusive action on CC without attention to related problems will be ineffective. But Ghana lacks the ability to influence global action in any significant way. As such it can only adopt an incremental strategy within the country and regionally as in WRC's adopted comanagement of international rivers and major internal watersheds</p>

(continued)

Table 2. (continued)

Rittel and Weber	CC and water supply in Ghana
The existence of a discrepancy representing a wicked problem can be explained in numerous ways. The choice of explanation determines the nature of the problem's resolution	No meaningful locally designed water adaptation interventions against CC. Agencies such as EPA, WRC, and NGOs all seem to tailor their strategies toward internationally driven initiatives such as MDGs and so on. This is justified as being part of the international community or determination to secure funding sources. Traditional authority and informal knowledge are often sidelined by experts from state and formal agencies
The planner has no right to be wrong (Planners are liable for the consequences of the actions they generate)	The precautionary principle is implied here, a key element of Ghana Water Policy. However, current Ghanaian practice places no liability on planners and policy makers for unintended mistakes after due diligence, probably justifiably so because learning from experience and even mistakes (adaptive) is fundamental to building capacities against latent uncertainties of CC. Nonetheless, the principle compels planners and implementers in CC and water resources to ponder their actions carefully to minimize negative externalities of their actions on others

Note: CC= climate change; NGO = nongovernmental organization; EPA = Environment Protection Agency; WRC = Water Resources Commission; CWSA = Community Water and Sanitation Agency.

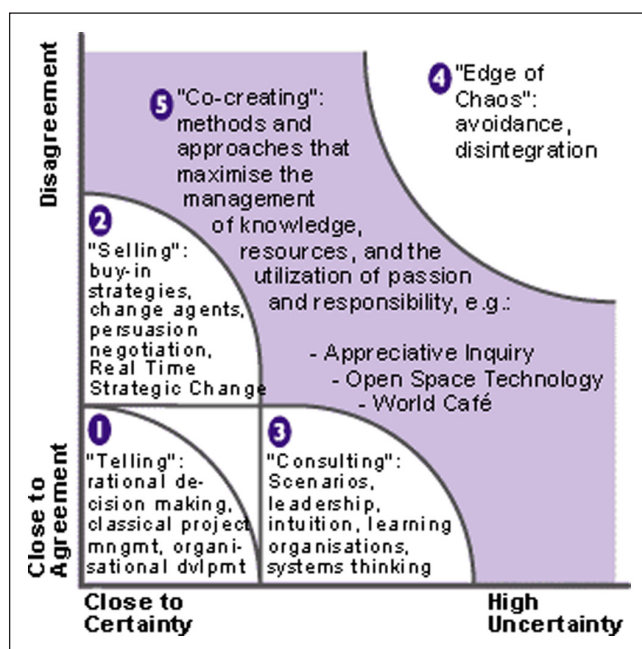


Figure 2. Ralph Stacy's agreement and certainty matrix
Source: Adapted from Zimmerman (2001).

in innovation and a shift from past practices to create new modes of operating because the predictive power of traditional management approaches becomes ineffective here (Zimmerman, 2001). In elaborating on the model, the authors provide a typology for responding to different levels of dilemma and complex scenarios, requiring changing approaches in moving from agreement and certainty. Within this framework, specific tools or mechanisms can be applied to respond to complex issues, including Mess Mapping and

Resolution Mapping Processes (see Horn & Weber, 2007), General Morphological Analysis (Ritchey, 2005-2011), and ACM. This article focuses on ACM, not on the other two.

ACM seeks to legitimize decision making in complex situations through effective collaboration, flexible governance, and continuous learning informed by experience. Three phases of Stacy-Zimmerman's model arranged backward (Table 3) fits the ACM idea of water management under complexity, although the first phase is a necessary condition for responding to severe consequences on water resources under changing climatic conditions as the Ghanaian scenario demonstrates. ACM may be useful for Ghana because it is a dynamic approach imbued with complex and adaptive systems thinking with internal capacity to minimize ineffectiveness and inefficiencies in existing social and institutional models, while capitalizing on opportunities of instrumental gains from prior existing institutions. Particularly, ACM will help strengthen the capacities of rural water management systems to adapt to climate change because of its emphasis on equity and power balance through stakeholder deliberative processes, strengthening horizontal and cross-scale linkages, and creating space for iterative learning and opportunities for coexistence and interaction among different knowledge systems, thereby giving legitimacy to decisions and actions.

ACM

ACM is a successor to earlier approaches (resilience, adaptive, and later comanagement) that emphasized social and ecological dynamism, network governance, resilience, and capacity building process through learning from experiences (Berkes, 2009). ACM emerged in the late 1970s against the backdrop of failures in community-based sustainable

Table 3. Changing Management Approaches in Moving from Agreement and Certainty

Possible approach	Description	Comments
1. Seek patterns	Scan “chaotic and disorganized” systems for emerging organizations and patterns	Assumption here is that object of study is approaching high-dimensional chaos. Task is to identify emerging patterns that might suggest emerging level of organization
2. Convene	Bring representatives of various complex adaptive systems together in an attempt to facilitate self-organization and emergence. Compare active convening with observation of entities coming together	Insufficient involvement or direct control to allow formal intervention. Action limited to convening in hopes that interaction and change will emerge. Less-structured intervention than above example
3. Examine and describe patterns	Observe interactions between complex adaptive systems that are beyond the leader’s ability to affect or convene	The task here is to understand. Systems are sufficiently large or removed to preclude any intervention
4. Convene and intervene	Bring representatives of various CASs together to facilitate self-organization and emergence. Use process tools to confront inherent paradoxes and to seek change through leveraging Morgan’s 15% opportunity. Compare approaches with and without goals	Primary step is to convene representatives of involved complex adaptive systems. Secondary step is structured, planned “intervention” that actively attempts to “move to a new attractor” (Per G. Morgan)

Source: Adapted from Zimmerman, 2001.

Note: CAS = Complex Adaptive Systems

development that painted images of consensual communities and stable environments (Leach, Mearns, & Scoones, 1997). It is an integration of adaptive management and comanagement (Armitage, Berkes, & Doubleday, 2007; Berkes, 2007; Plummer & FitzGibbon, 2007). Consequently, it combines iterative learning in adaptive management with the central element of linkages in collaborative management where rights and responsibilities are jointly shared (Berkes, 2007; Dolšák et al., 2003). Scalar issues are important to ACM as it draws the linkages between stakeholder networks and access to political, technical, social, and economic resources (adaptive capacities) of local communities and households. The local scale is viewed as the place where “issues of management performance are felt most directly” but emphasize “a flexible system for environment and resource management that operates across multiple levels and with a range of local and non-local organizations and actors” (Armitage et al., 2007, p. 5). There is no single all-encompassing definition of ACM. However, learning by doing, integrating multiple knowledge systems, emphasizing flexibility of management structures, and advancing collaboration through power sharing at multiple scales remain central (Plummer & FitzGibbon, 2007).

Climate change adaptation involves SES and therefore fits the complexity or adaptive systems framework. The transitional nature of global climate system implies that adaptation is not geared toward a predictable end state. Rather, it is about a newly configured system, which is just one of potential multiple end states (Gunderson & Holling, 2002; Walker et al., 2002). This suggests an element of path dependence or contingency in the possible outcomes of the adaptive approach. As

such “we must focus on learning to live within systems, rather than ‘controlling’ them” (Walker et al., 2002, p. 2). This is the basis of Gunderson and Holling’s (2002) “panarchy” concept (a hierarchy of nested adaptive cycles across time and space). It is also the basis of their indictment against “development experts”: (a) ignorance of the key drivers of change in a dynamic system, and the distinctly different scales of time and space they operate therefore exposing conventional ecological management practices to self-destructive-controlled ecological interventions along with the sociocultural structures that support it and (b) ignorance of the connectedness and linkages in ecology and society, as well as knowledge systems. Armitage et al. (2007) concluded,

Complex systems thinking offers a way of examining, describing, interpreting, and cognitively structuring not only ecological systems but also increasingly linked socio-ecological systems. Specifically, complex systems thinking highlights the dynamic, nonlinear relationships among coupled social and ecological phenomena that result in discontinuities, surprises, system flips, and the potential for multiple equilibrium states. (p. 7)

What Should ACM for Ghana Look Like?

The underpinning tenets of ACM are informative for Ghana because climate change is a young and understudied subject in the country. Therefore, the full extent of intricate interconnections of climate change with other sectors and ecological resources (including water), and associated

impacts on their vulnerabilities are not well understood. Ghana's environmental and water agencies should work with the assumption that climate change is exacerbating water vulnerabilities and pushing water resources management capacities to their tether. The major task is to encourage formal research and traditional learning institutions to identify emerging patterns and their levels of operation and a disaggregated impact assessment on people (Table 3, Phase 1). It is especially relevant for rural water supply because rural communities in Ghana lag behind in most capitals and hence their low adaptive capacities.

A typical ACM for Ghana must specifically emphasize continuous learning in an iterative manner within networks and continuous information sharing and education as its overriding objective for local management institutions (Pahl-Wostl, 2007; Tschakert & Dietrich, 2010). The effects of climate change will linger for a while. Therefore, institutional strategies that have proved capable of coping with extreme climatic events must be identified and incorporated into regional and national adaptation plans until more adaptable ones are found. In addition, formal education must incorporate lessons on mitigation and adaptation because today's students are future policy makers. Extension workers must be informed and motivated to educate local people but must be willing to be receptive to local wisdom and practices. Cultural and religious groups must be targeted for education because people with formal education and nontraditional beliefs tend to flout traditional ecological norms that have been the mainstay of rural water management (Appiah-Opoku & Hyma, 1999; Gyampoh et al., 2009; Sarfo-Mensah & Oduro, 2007). Local communication systems (e.g., community radios) must use local dialect to reach their communities to be abreast with new and tested ideas as well as improve their technical capacities. In this regard, Ada Community Radio is worth mentioning in the way it interacts with and helps educate and mobilize local people about environment and climate change issues in the Dangme East District (Larweh, 2006; Mensah, 2012). This approach has proved useful not only in bonding but also in bridging cross-scale linkages among nations (Pahl-Wostl, 2007; Stringer et al., 2006). NGOs, Civil Society Organizations (CSOs), and international aid agencies must be given easy access to institutional information and local communities to help in capacity building.

In addition, emphasis should be placed on institutional bricolage, with recognition of informal knowledge as a legitimate source of information for climate and water management issues because they have been useful for generations in helping local communities adjust to environmental disturbances. This will require codification of some sort to preserve them for future generations similar to the Peoples Biodiversity Register in India (Gadgil, Seshagiri Rao, Utkarsh, Pramod, & Chatre, 2000) or perhaps mainstream them into national adaptation plans. For instance, Tengo and Belfrage (2004) found examples of how old practices served as a source of adaptation for dealing with new conditions,

and that new knowledge was adjusted to local conditions in both Sweden and Tanzania.

We must acknowledge the importance of ethics and social justice in environmental problems. They cannot be resolved without the participation of those most affected. In fact, a satisfactory resolution may well hinge on special sorts of local knowledge and institutions that will only become available if local people are welcomed as active and influential participants. Perhaps, if room is made for them at the table, a new science that incorporates traditional knowledge and values will emerge. (Berkes & Folke, 1998, quoted in Ludwig, 2001, p. 763)

Conflicts over control of resources and decision-making authority have been observed between decentralized bodies and traditional authorities and also between local decentralized units and community water organizations (Anani, 1999; Jackson & Gariba, 2002). Such conflicts must be addressed swiftly, and the boundaries of authority of these institutions must be addressed clearly and responsibly. This will require collaboration at all levels where trust and respect are pursued (building social capital). This framework will focus on bringing in vulnerable groups—poor and women—by deliberately targeting them and creating space for them to participate in decision making. It will require different negotiation skills among facilitators, policy makers, and implementers to bridge the gap between local authorities and government institutions over control of water resources. Within this context, blanket cash-and-carry approaches for accessing water will be reevaluated based on specific community context allowing each community to come up with an arrangement suitable to its needs. This will minimize conflict endemic in the current arrangement. Finally, climate and water policies must be linked with broad social and economic activities of rural people. As Brown and Crawford (2008) suggested, Ghana needs holistic adaptation measures that address the full range of development problems it faces that are tangentially related to climate change, not just those that arise as a result of climate change. Collectively, these will help overcome the observation that because climate change transcend the local scale the tools to equip adaptive learning in Africa are sparse, as a result of communication deficiencies which make it difficult to integrate science information into climate policy and practice; and lack of learning tools that encourage adaptation process, including experimentation and innovation in building resilience in complex high risk socio-ecological systems (Tschakert & Dietrich, 2010).

Conclusion

While the preceding discussion indicates that climate change is a wicked problem defying easy solutions, the vulnerability of people is a matter of degree based on specific contexts.

Some nations, regions, groups, and individuals are better able to ameliorate their exposures to climate change, whereas in others vulnerability can easily deteriorate into disasters. Therefore, the key issue to tackling climate change hinges on adaptive capacities based on abilities derived from availability and access to capitals that empower communities and individuals to act appropriately. In the case of Ghana, climate change involves a level of complexity that goes beyond the capacity of national and local water institutions to meaningfully manage. The enormity has arisen from, among other things, scalar dimensions of climate, diversity of climate, and water-related functions, and the multitude of linkages that these functions have with peoples' livelihoods. The WRC, CWSA, Ministries, and agencies responsible for environmental services seem to be doing alright at the international and national levels. But the linkages at the subnational and local levels are weak. The way forward is to maintain flexible collaborative management systems that foster participation in decision making, social capital formation, and coexistence of formal and informal knowledge systems with the ultimate intent of engendering social learning in an adaptive manner.

Whether global forces are understood or not, or action is taken by global powers to address climate change or not, local people cannot stop carrying on with their lives. They will do what is within their power to ensure that their livelihoods and communities are not violently disrupted. Local methods might be different, even insufficient, but not to be frowned upon because that would amount to throwing away the babe together with the bath water, denying local people the opportunity to participate in their development process. Rather, the Ghana government through its designated water and environmental institutions must empower rural communities by strengthening their capacities to take charge of their own destinies as they have done for generations. In pursuance of this objective, ACM is a reasonable management approach for Ghana because it focuses on sustainable development based on ecologically conscious, inclusive, and network governance principles making it attractive in managing complex situations such as climate change.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

Funding

The author(s) received no financial support for the research and/or authorship of this article.

References

- Anani, K. (1999). *The pursuit of politics of sustainable livelihoods: Focus on governance in Ghana* (Doctoral dissertation). University of Guelph, Ontario, Canada.
- Appiah-Opoku, S., & Hyma, B. (1999). Indigenous institutions and resource management in Ghana. *Indigenous Knowledge and Development Monitor*, 7(3), 15-17.
- Arku, F. S. (1993). *Drought and rainfall variability in Ghana from 1969 to 1992* (Unpublished master's thesis). University of Bergen, Norway.
- Arku, F. S., & Arku, C. (2010). I cannot drink water on an empty stomach: A gender perspective on living with drought. *Gender & Development*, 18, 115-124.
- Armitage, D., Berkes, F., & Doubleday, N. (2007). Introduction: Moving beyond co-management. In D. Armitage, F. Berkes, & N. Doubleday (Eds.), *Adaptive co-management: Collaboration, learning, and multi-level governance* (pp. 1-18). Vancouver, Canada: UBC Press.
- Australian Public Service Commission. (2007). *Tackling wicked problems: A public policy perspective*. Retrieved from <http://www.apsc.gov.au/publications07/wickedproblems.pdf>
- Awumbila, M., & Momsen, J. H. (1995). Gender and the environment: Women's time use as a measure of environmental change. *Global Environmental Change*, 5, 337-346.
- Ayers, J., & Dodman, D. (2010). Climate change adaptation and development. I: The state of the debate. *Progress in Development Studies*, 10, 161-168.
- Berkes, F. (2007). Adaptive co-management: Exploring the many faces of co-management. In D. Armitage, F. Berkes, & N. Doubleday (Eds.), *Adaptive co-management: Collaboration, learning, and multi-level governance* (pp. 19-29). Vancouver, Canada: UBC Press.
- Berkes, F. (2009). Evolution of co-management: Role of knowledge generation, bridging organizations and social learning. *Journal of Environmental Management*, 90, 1692-1702.
- Berkes, F., & Folke, C. (Eds.). (1998). *Linking social and ecological systems: Management practices and social mechanisms for building resilience*. Cambridge, UK: Cambridge University Press.
- Birner, R., Schiffer, E., Asante, F., Gyasi, O., & McCarthy, N. (2005). *Analysis of governance structures for water resources management in the White Volta Basin Ghana* (Final Report). Washington, DC, USA: IFPRI.
- Both ENDS. (2007). *Adapting to climate change: How local experiences can shape the debate* (Briefing Paper). Retrieved from <http://www.bothends.org/index.php?page=6&documentId=14>
- Brown, O., & Crawford, A. (2008). *Assessing the security implications of climate change for West Africa: Country case studies of Ghana and Burkina Faso*. Manitoba, Canada: IISD.
- Brown, V. A., Harris, J. A., & Russell, J. Y. (Eds.). (2010). *Tackling wicked problems: Through the transdisciplinary imagination*. London, England: Earthscan.
- Bunce, M., Rosendo, S., & Brown, K. (2010). Perceptions of climate change, multiple stressors and livelihoods on marginal African coasts. *Environment, Development and Sustainability*, 12, 407-440.
- Conklin, J. (2001). *Wicked problems and social complexity*. Cognexus Institute. Retrieved from <http://cognexus.org/wpf/wickedproblems.pdf>
- Dankelman, I., Alam, K., Ahmed, W. B., Gueye, W. D., Fatima, N., & Mensah-Kutin, R. (2008). *Gender, climate change and human security: Lessons from Bangladesh, Ghana and Senegal*. Report

- has been prepared for ELIAMEP by The Women's Environment and Development Organization (WEDO) with ABANTU for Development in Ghana, ActionAid Bangladesh and ENDA in Senegal. Retrieved from <http://www.wedo.org/wp-content/uploads/hsn-study-final-may-20-2008.pdf>
- Dolšák, N., Brondizio, E. S., Carlsson, L., Cash, D. W., Gibson, C. C., Hoffmann, M., & Ostrom, E. (Eds.). (2003). *Adaptation to challenges. The commons in the new millennium: Challenges and adaptation* (pp. 337-360). Cambridge, MA: MIT Press.
- Douglas, I., Alam, K., Maghenda, M., McDonnell, Y., Mclean, L., & Campbell, J. (2008). Unjust waters: Climate change, flooding and the urban poor in Africa. *Environment & Urbanization*, 20, 187-205
- Environment Protection Agency. (2000). *Ghana's initial national communication under the United Nations Framework Convention on Climate Change*. Accra, Ghana: Author.
- Ferguson, A., & Rankin, C. (2005). *Indicators and strategies for adapting to climate variability in food security programming for Sub-Saharan Africa*. Gatineau, Quebec, Canada: CIDA.
- Flamos, A., & Begg, K. (2010). Technology transfer insights for new climate regime. *Environment, Development and Sustainability*, 12, 19-33.
- Gadgil, M., Seshagiri Rao, P. R., Utkarsh, G., Pramod, P., & Chatre, A. (2000). New meanings for old knowledge: The people's biodiversity register program. *Ecological Applications*, 10, 1307-1317.
- Gunderson, L. H., & Holling, C. S. (2002). *Panarchy: Understanding transformations in human and natural systems*. Washington, DC: Island Press.
- Gyampoh, B. A., Amisah, S., Idinoba, M., & Nkem, J. (2009). Using traditional knowledge to cope with climate change in rural Ghana. *Unasylva*, 60, 231-232.
- Gyampoh, B. A., Idinoba, M., & Amisah, S. (2008). Water scarcity under a changing climate in Ghana: Options for livelihoods adaptation. *Development*, 51, 415-417.
- Gyimah, C., & Thompson, E. S. (2008). Women's participation in local governance in Ghana: The case of Nadowli District of the Upper West Region. *Studies in Gender and Development in Africa*, 1, 58-77.
- Hamilton, C. (1999). Justice, the market and climate change. In N. Low (Ed.), *Global ethics and the environment* (pp. 90-105). New York, NY: Routledge.
- Horn, R. E., & Weber, P. R. (2007). *New tools for resolving wicked problems*. MacroVU and StrategyKinetics L.L.C. Retrieved from http://www.strategykinetics.com/New_Tools_For_Resolving_Wicked_Problems.pdf
- Intergovernmental Panel on Climate Change. (2001). *Climate change 2001: Impacts, adaptation and vulnerability*. Cambridge, UK: Cambridge University Press.
- Intergovernmental Panel on Climate Change. (2007). *Freshwater resources and their management. Climate change 2007: Impacts, adaptation and vulnerability*. In M. L. Parry, O. F. Canziani, J. P. Palutikof, P. J. van der Linden, & C. E. Hanson (Eds.), *Contribution of Working Group II to the fourth assessment report of the Intergovernmental Panel on Climate Change* (pp. 173-210). Cambridge, UK: Cambridge University Press.
- Jackson, E. T., & Gariba, G. (2002). Complexity in local stakeholder coordination: Decentralization and community water management in Northern Ghana. *Public Administration and Development*, 22, 135-140.
- Kankam-Yeboah, K., Amisigo, B., & Obuobi, E. (2011). *Climate change impacts on water resources in Ghana*. Ghana: UNESCO.
- Lambrou, Y., & Piana, G. (2006). *Gender: The missing component of the response to climate change*. FAO. Retrieved from http://www.fao.org/sd/dim_pe1/docs/pe1_051001d1_en.pdf
- Larweh, K. (2006). And our "Perk" was a crocodile: Radio ada and participatory natural resource management in Obane, Ghana. In G. Bessette (Ed.), *People, land, and water: Participatory development communication for natural resource management*. Earthscan/IDRC. Retrieved from http://www.crdi.org/en/ev-105004-201-1-DO_TOPIC.html
- Laube, W. (2007). The promise and perils of water reforms: Perspectives from Northern Ghana. *Afrika Spectrum*, 42, 419-437.
- Leach, M., Mearns, R., & Scoones, I. (1997). Challenges to community-based sustainable development: Dynamics, entitlements and institutions. *IDS Bulletin*, 28(4), 4-14.
- Leroux, M. (2001). *The meteorology and climate of Tropical Africa*. Chichester, UK: Praxis Publishing.
- Ludwig, D. (2001). The era of management is over. *Ecosystems*, 4, 758-764.
- Magadza, C. H. D. (2000). Climate change impacts and human settlements in Africa: Prospects for adaptation. *Environmental Monitoring and Assessment*, 61, 193-205.
- McGranahan, G., Balk, D., & Anderson, B. (2007). The rising tide: Assessing the risks of climate change and human settlements in low elevation coastal zones. *Environment & Urbanization*, 19(1), 17-37.
- Mensah, K. B. (1998). Restructuring the delivery of clean water to rural communities in Ghana: The institutional and regulatory issues. *Water Policy*, 1, 383-395.
- Mensah, K. O. (2012). *Linking adaptive co-management with precaution to adapt rural water supply to climate change, Ghana* (Unpublished doctoral dissertation). University of Guelph, Ontario, Canada.
- Mensah-Kutin, R. (2008). *Gender, climate change and human security: Lessons from Bangladesh, Ghana and Senegal*. Prepared for ELIAMEP by WEDO with Abantu for Development in Ghana, ActionAid Bangladesh, and ENDA in Senegal. Retrieved from <http://www.wedo.org/wp-content/uploads/hsn-study-final-may-20-2008.pdf>
- Odame-Ababio, K. (2003). Putting integrated water resource management in practice—Ghana's experience. *Proceedings of the African Regional Workshop on Water Management*, Nairobi, Kenya.
- Pahl-Wostl, C. (2007). Transitions towards adaptive management of water facing climate and global change. *Water Resource Management*, 21, 49-62.
- Patton, M. Q. (2011). *Developmental evaluation: Applying complexity concepts to enhance innovation and use*. New York, NY: Guilford.

- Plummer, R., & FitzGibbon, J. E. (2007). Connecting adaptive co-management, social learning and social capital through theory and practice. In D. Armitage, F. Berkes, & N. Doubleday, *Adaptive co-management: Collaboration, learning and multi-level governance* (pp. 38-61). Vancouver, British Columbia, Canada: UBC Press.
- Ritchey, T. (2005-2011). *Wicked problems: Structuring social messes with morphological analysis* Swedish Morphological Society. Available from www.swemorph.com
- Rittel, H., & Webber, M. (1973). Dilemmas in a general theory of planning. *Policy Sciences*, 4, 155-169.
- Sarfo-Mensah, P., & Oduro, W. (2007). *Traditional natural resources management practices and biodiversity conservation in Ghana: A review of local concepts and issues on change and sustainability* (Working Paper No. 90). FEEM. Retrieved from <http://www.feem.it/userfiles/attach/Publication/NDL2007/NDL2007-090.pdf>
- Schiffer, E., McCarthy, N., Birner, R., Waale, D., & Asante, F. (2008). *Information flow and acquisition of knowledge in water governance in the upper east region of Ghana* [IFPRI Discussion Paper 00820]. Washington, DC: Environment and Production Technology Division.
- Sharma, N. P., Damhaug, T., Gilgan-Hunt, E., Grey, D., Okaru, V., & Rothberg, D. (1996). *African water resources: Challenges and opportunities for sustainable development* (World Bank Tech. Paper No. 331). Washington, DC.
- Stacy, R. (1996). *Strategic management and organisational dynamics* (2nd ed.). London, England: Pitman.
- Stringer, L. C., Dougill, A. J., Fraser, E., Hubacek, K., Prell, C., & Reed, M. S. (2006). Unpacking "participation" in the adaptive management of social-ecological systems: A critical review. *Ecology & Society*, 11, 39. Retrieved from <http://www.ecologyandsociety.org/vol11/iss2/art39/>
- Tengo, M., & Belfrage, K. (2004). Local management practices for dealing with change and uncertainty: A cross-scale comparison of cases in Sweden and Tanzania. *Ecology & Society*, 9, 4. Retrieved from <http://www.ecologyandsociety.org/vol9/iss3/art4/>
- Tschakert, P., & Dietrich, K. A. (2010). Anticipatory learning for climate change adaptation and resilience. *Ecology & Society*, 15, 11. Retrieved from www.ecologyandsociety.org/vol15/iss2/art11/
- Tutuah-Mensah, A. A. (2009, October 19-21). *Implications of climate change on gender*. Paper presented at the three day science policy dialogue at Centre for African Wetlands, University of Ghana, Legon.
- United Nations Development Programme. (2008). *National action programme to mainstream climate change into Ghana's development*. Retrieved from www.undp-gha.org/project.php?page=26
- United Nations Framework Convention on Climate Change. (1998). *Kyoto Protocol to the United Nations framework convention on climate change*. Report of the conference of the parties on its third session, Kyoto, December 1-11, 1997. UNFCCC. Addendum, Part 2: Action taken by the Conference of the Parties at its third session. Decision 1/CP.3, Annex (FCCC/CP/1997/7/Add.1). Bonn, Germany: Author.
- United Nations Framework Convention on Climate Change. (2006, September 21-23). Background paper on the impacts, vulnerability and adaptation to climate change in Africa for the African Workshop on adaptation implementation of decision 1/CP of the UNFCCC Convention, Accra, Ghana.
- van der Geest, K. (2004). *"We're managing" climate change and livelihood vulnerability in Northwest Ghana*. Leiden, Netherlands: African Studies Centre.
- Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., & . . . Pritchard, R. (2002). Resilience management in social-ecological systems: A working hypothesis for a participatory approach. *Conservation Ecology*, 6, 14. Retrieved from <http://www.consecol.org/vol6/iss1/art14>
- Water Resources Commission. (2010). Newsletter of the climate change adaptation project. *Climate Adapt*, 2(1), 1-2.
- Wilbanks, T. J. (1999). Global change in local places: How scale matters. *Climate Change*, 43, 601-623.
- Zimmerman, B. (2001). *Edgeware-Aides: Ralph Stacy's agreement and certainty matrix*. Toronto, Canada: York University.

Bios

John FitzGibbon is a professor in the School of Environmental Design and Rural Development and a director of the Rural Studies Program, University of Guelph. His major interests and works include source water protection, environmental management, community-based natural resource management, environmental farm planning, and nutrient management planning.

Kenneth O. Mensah is a PhD candidate in rural studies, School of Environmental Design and Rural Development, University of Guelph. His interests are in planning and policy of urban-rural systems, environment and water resources management, gender, international development, and participatory governance with areal focus on sub-Saharan Africa.