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Agricultural Expansion and Water Pollution: The Yin-Yang in the Quality of Natural Water Resources

Joel Onyango, Kenneth Irvine, J.J. A. Van Bruggen, Nzula Kitaka and Norbert Kreuzinger

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Dr. Joël Houdet
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Agricultural Expansion and Water Pollution: The Yin-Yang in the Quality of Natural Water Resources

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Abstract

Global increased agricultural productivity aims at meeting the food and commercial demands on agriculture. This boost is associated with agricultural expansion practices including irrigation and use of fertilizers, which could increase negative environmental effects, such as natural water resources contamination. These require robust management mechanisms, including adequate policies which recognise and address increasing agricultural production trends and the associated water risks. Accordingly, this issue paper explores the drivers and pressures of water pollution from the perspective of agricultural expansion. It offers insights into the implications of this expansion for water resources and discusses the necessary policy responses for the agriculture and water sectors, through several case studies. The paper recognises the efforts put forward by regional bodies and national policies in establishing water quality guidelines. However, it also emphasises the need for such guidelines to take better account of the increasing demand and subsequent supply of fertilizers and pesticides, and of the resulting water contamination.

1. Introduction

Global increased agricultural productivity aims at meeting the food and commercial demands, and expectations on agriculture (Henningsson et al., 2004; Nellemann et al., 2009; Godfray et al., 2010; Alexandratos and Bruinsma, 2012; FAO, 2013). This boost is associated with agricultural expansion practices including irrigation, and use of fertilizers and pesticides aimed at increasing yields per unit area (FAO, 2003; FAO, 2006; Royal Society of London, 2009). However, these practices pose a risk to the environment, enhancing effects such as habitat modification or loss and decline in terrestrial and aquatic ecosystem services (Tilman et al., 2001; Groombridge and Jenkins, 2002; Millennium Ecosystem Assessment, 2005; BirdLife, 2008; IUCN, 2008; Alkemade et al., 2009).

Application rate of fertilizers increased globally from less than 100 $KgHa^{-1}$ in 2004 to more than 130 $KgHa^{-1}$ in 2011 depicting on average a 30% increase in 7 years (The World Bank Group, 2014). On the other hand, the pesticides market expanded by 50% at USD 13 billion between 2000 and 2007, resulting to a USD 39billion trade market for pesticides (Zhang et al., 2011; Fishel, 2013). The increase in the use and demand of fertilizers and pesticides enhance the environmental risks associated with agricultural intensification (Godfray et al., 2010). As a result, the risks of aquatic ecosystems contamination as recipients of nutrients from fertilizers and pesticide residues from pest control is elevated (Papendick et al., 1986; Sherman and Hempel, 2008).

Nutrients and pesticides contamination in aquatic ecosystems has potential for a wide range of impacts such as eutrophication and ecosystem poisoning (Aragón-Noriega and Calderon-Aguilera, 2000; UNEP, 2001). Nutrients such as nitrogen and phosphorus are major elements of fertilizers (Heffer and Prud'homme, 2013) and their magnitude of occurrence commonly determines the trophic state of aquatic ecosystems. In limitation of nitrogen and phosphorus, aquatic ecosystems are less productive, whereas their enrichment results in highly productive or eutrophic aquatic ecosystems (Ongley, 1996). On the other hand, pesticide residues in aquatic ecosystems have different effects including: death, cancers, tumours and lesions on the organism; reproductive inhibition or failure; and disruption of endocrine system (Weston et al., 2004). Subsequently, nutrients and pesticides could modify the occurrence and distribution of aquatic organisms as well as the aquatic ecological processes.

This issue paper explores the drivers and pressures of water pollution through the aspects of agricultural expansion demands. It offers insight into implications of the expansion to water resources and assesses the policy response necessary for the agriculture and water sectors, with case study examples.

2. Agricultural intensification: driver and pressure to water resources contamination

Within the Organisation for Economic Cooperation and Development (OECD) Driver-Pressure-State-Impact-Response (DPSIR) scheme, drivers, originating and acting globally, regionally or locally, are the social, demographic and economic developments in societies and the corresponding changes in life styles, overall levels of consumption and production patterns (US EPA, 2011). Ideally drivers are often defined as socioeconomic sectors that fulfil human needs for instance agricultural intensification to enhance food production (Benini et al., 2010). On the other hand, intentionally or not, human induced drivers may exert pressure on the environment including release of substances into the environment (such as fertilizers and pesticides), consumption and demand of resources, and land use changes (US EPA, 2011).

This issue paper contextualizes agricultural production and subsequent intensification as main drivers, while contamination is highlighted as pressures into the current state of the water resources, as a factor of increasing demand for fertilizers and pesticides (Figure 1).

2.1 Drivers

Within the last half a century global food production has increased, especially for cereals, by 138% from 1.84 billion tones in 1961 to 4.38 billion tones in 2007 (Royal Society of London, 2009). In theory, per capita food available has increased by 29% compared with availability in 1960s although practically there are regional and country specific differences (Royal Society of London, 2009). At the same time, population increase and dietary changes have resulted in elevated food demand expected to reach 1.1% per year in the period 2005/2007 to 2050 (Alexandratos and Bruinsma, 2012). The elevated demand perpetuates food insecurity with 2 billion people suffering from micro-nutrients deficiency and 842million being chronically undernourished (Wheeler and von Braun, 2013; FAO, 2013). With expected population of 8.3 billion to 10.9 billion by 2050 (UN-DESA, 2013), the global food production will need to be increased by 60% to meet the need by 2050 (Alexandratos and Bruinsma, 2012). The increase food production to meet the current and future demands, agricultural expansion through clearing more crop land or intensive use existing crop land are viewed as alternatives, with their potential environmental impacts not well understood (Tilman et al., 2011). These alternatives are accompanied by use of agricultural inputs including fertilizers and pesticides. For example use of nitrogen fertilizers is predicted to reach between 225Mt to 250Mt by 2050 which would be 2.25 to 2.5 times the use in 2005 (Tilman et al., 2011; Royal Society of London, 2009).

Moreover, reforms in regional agricultural policies have targeted availing more funds or enhancing access to agricultural inputs. The European Union Common Agriculture Policy established 1962 targeted to make agriculture rely less on the EU budget, yet produce enough food for the EU and global population, and enhance farmer earnings through funding rural development and farming practices and compensations (European Commission, 2012). On the other hand, the deficit in fertilizer demand and supply for the African continent led to the 2006 Abuja Africa Fertilizer Summit, where the African states put into effect attempts to develop regional fertilizer policies (FAO, 2008) including tariff adjustments and fertilizer subsidies (GoK, 2009) to enhance fertilizer availability and use by farmers.

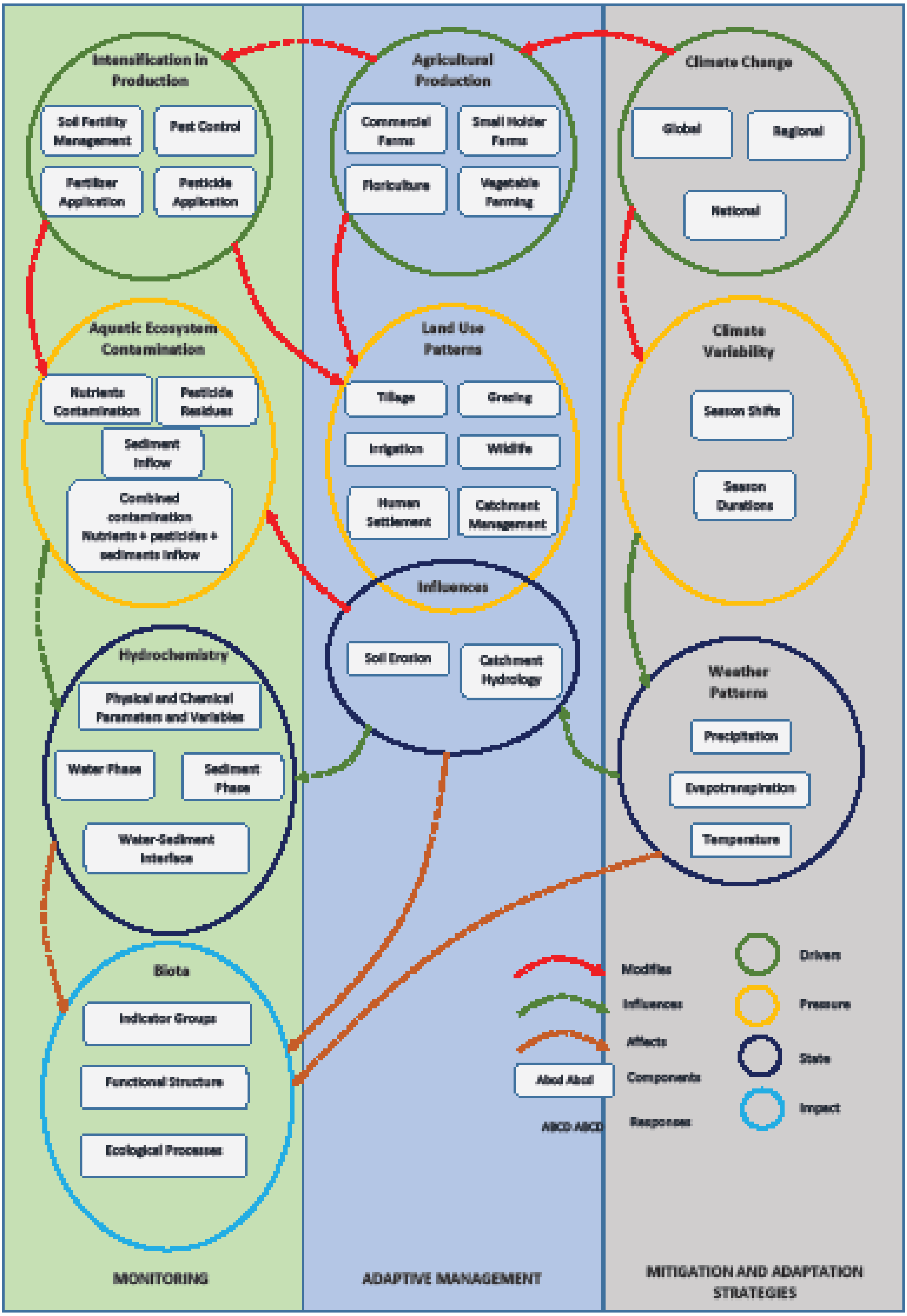

Figure 1: Illustration of the interlink of drivers and pressures

FAO (2008) and FAO (2011) predicted an increase by 4% in global fertilizer demand between 2007 and 2015, whereas the actual demand increased by 8% between 2009 and 2013 from 163 to 176 million metric tons per year (Heffer and Prud'homme, 2012; Heffer and Prud'homme, 2013). With that in mind, the prediction by Heffer and Prud'homme (2013) that the demand will increase by 18% between 2009 and 2018, indicates the exponential growth in the demand and consequently use of the fertilizers. Heffer and Prud'homme (2013) continue to indicate that the demand for fertilizer will continue to increase in most regions except North America, whereas regions with low application rates or expanding cultivation land including Eastern Europe, Central Asia, Latin America, and Africa will have the highest rate of increase in demand. Africa's demand for fertilizer was 2.5% of the global consumption by 2010 with Egypt, South Africa, Morocco and Nigeria being the main consumers in the region (FAO, 2011). The region consumed 2.7% of the nitrogen nutrients, 2.4% phosphates and 1.7% potash in 2010 of global use, with a projected growth rate of 1.9%, 3.3% and 4.3% for nitrogen, phosphates and potash, respectively, between 2011 and 2015 (Heffer and Prud'homme, 2013). Forecasts on supply and demand indicate that the African region will continue to supply more than 30% of global phosphate fertilizer (especially from Morocco, South Africa, Egypt, Algeria, Senegal, Tunisia, Togo, Niger, Gabon and Uganda), followed by nitrogen (especially from Nigeria, Gabon, Tanzania, Angola and Mozambique), while continuing to import its potash needs (except for Tunisia, Libya, Egypt, Ethiopia, Congo and Morocco) (Van Kauwenbergh, 2006; FAO, 2008; FAO, 2011; KPMG, 2013).

At the same time, pest control is required in agricultural expansion to increase yields, quality and economic returns (Paula, 2011; Kellogg et al*.,* 2000). Use of pesticides including insecticides, fungicides, herbicides fumigants, rodenticides, growth regulators, defoliators, surfactants and wetting agents is fundamental in pest control (Birech et al*.,* 2006; Kuniuki, 2001; Knutson, 1999). The market value of pesticides trade has increased from US$ 850 million in 1960 to US$ 39 billion in 2007 (Zhang et al*.,* 2011; Fishel, 2013). Out of the 22 chemicals listed under Persistent Organic Pollutants (POPs) by Stockholm Persistent Organic Pollutants Convention 2001 (SPOPC), 15 are pesticides (or are applied as pesticides). These include α, β and γ- Hexachlorocyclohexane, and DDT (Secretariat of the Stockholm Convention, 2012). Negotiations on specific compounds regulations within the developing countries are hampered by inadequacy in data and information about the sources, releases and environmental concentrations of the POPs (Bouwman, 2004; Porta and Zumeta, 2002). Asia is the second largest consumer of pesticides after Europe, with China, USA, France, Brazil and Japan in the forefront of production, consumption and trade of pesticide products (Zhang et al*.,* 2011). The use of pesticides is indispensable in most developing countries, especially the use of herbicides, although, owing to the hot and humid conditions in tropical countries insecticides are more common (Madadi et al*.,* 2005). Africa consumes 4% of the global market of 75,000-100,000 tonnes per year of pesticide active ingredients with averagely low application rates of 1.85Kg/ha compared with the global average of 3.82 Kg/ha (PAN UK, 2008; FAOSTAT, 2014). Pesticide active ingredients are effective in pest control, yet of risk to human and environmental health systems (PAN UK, 2008; Quinn et al*.,* 2011).

2.2 Pressures

Inorganic fertilizers are used to increase agricultural production and are a fundamental component of agricultural intensification (IFDC, 2012; FAO, 2011). The increase (and further predicted increase) in fertilizer demand (Van Kauwenbergh, 2006; Heffer and Prud'homme, 2013), and policies that promote use of fertilizers (FAO, 2008; GoK, 2009), coupled with the declining soil fertility (Gruhn et al., 2000; van Vuuren et al., 2010; Cooper et al., 2011; Sverdrup and Ragnarsdottir, 2011; Koppelaar and Weikard, 2013), amplifies the risk that continued application of fertilizers pose on natural sustainability of aquatic ecosystems currently, and in the future (Stringer, 2013; FAO, 2001). This concern raises a critical knowledge need, for sustainable agricultural intensification approaches.

The increase in pesticide demand (PAN UK, 2008; FAOSTAT, 2014) and the necessity of the pesticide products raises concern as to what effects they could pose (Madadi et al., 2005), especially since majority of the persistent organic pollutants (PoPs) as documented by the Stockholm Persistent Organic Pollutants Convention 2001 (SPOPC) are pesticides (Secretariat of the Stockholm Convention, 2012; Bouwman, 2004). The use of pesticides is further complicated by the pesticide resistance which shows a steady increase posing a threat to agricultural productivity (IRAC, 2013; Bellinger, 1996; Porta and Zumeta, 2002). Control of *Anopheles* mosquito spreading malaria, for example, has been documented to be at a threat due to resistance to pyrethroids in Africa (Brooke et al., 2001; Quinn et al., 2011), skewing use of pesticides to more persistent pesticides such as DDT (Ranson et al., 2011; African Network for Vector Resistance, 2005). The potential consequences of pests' resistance to current pesticides in the market would result in use of more persistent pesticides in pest control elevating the toxicological risks to the recipient ecosystem, such as aquatic ecosystems.

The trend of fertilizer and pesticides use is on the rise. Although this is in the effort to enhance agricultural productivity, the consequences to the environment could be severe for the current or future state of the aquatic resources following contamination and subsequent exposure to aquatic biota. These consequences could be manifested through the independent effects of nutrients and pesticides or through the effects of a nutrient-pesticide combination.

3. Implication of nutrients and pesticides contamination on water resources

The uptake of nutrients by primary producers is the primary fate of nutrients within an aquatic ecosystem. When the nutrients from the fertilizers are taken up by primary producers, they enhance productivity within the aquatic ecosystem depending on the limitation of the aquatic system and the introduced nutrient (Ongley, 1996; Russo, 1985). Although chemical fertilizers can be used to supply 13 essential plant nutrients (Howarth and Marino, 2006), many aquatic ecosystems are nitrogen and/or phosphorus limited (Janus and Vollenweider, 1981), such that additions of nitrogen and/or phosphorus result in eutrophication (Howarth and Marino, 2006).

The effects of eutrophication vary depending on the level of nutrient enrichment. Eutrophication enriches food chains, enhancing primary production, and availing more energy up the aquatic food chain, resulting to generally more productive aquatic ecosystems through a bottom-up control (Ongley, 1996; Camargo and Alonso, 2006; Durand et al., 2011; Rabalais, 2002; Mesner and Geiger, 2010; Kitaka et al., 2002; Majozi et al., 2008). The increase in biomass as a result of enhanced productivity increases the amount of dissolved oxygen required by the decomposers to break down the organic matter resulting from the death of the aquatic biomass (Rabalais, 2002; Mesner and Geiger, 2010). This, in turn, increases the respiratory oxygen demand facilitating anoxic conditions causing death or increased susceptibility to diseases and infections of aquatic biota (Kitaka et al., 2002; Hubble and Harper, 2002). Species tolerant to high nutrient concentrations become more competitive following eutrophication, out-growing sensitive species, thereby reducing diversity and causing shifts in energy contributions within the aquatic food chains exhibiting a top-down trophic control (Koelmans et al*.,* 2001; Camargo and Alonso, 2006; Durand et al*.,* 2011). Aquatic organisms may produce toxins to inhibit occurrence or survival of other organisms and enhance their own competitive power (Nierenberg, 2001). Such toxins, for example cynotoxins produced by cyanobacteria, affect the diversity of aquatic ecosystem and may impact the food chain (Ongley, 1996; Camargo and Alonso, 2006). The varying effects following nutrient enrichment reduces the capacity of an aquatic ecosystem to enhance economic returns from ecosystem services such as fishing, since the survival of fish and the food chain supporting the fisheries can be greatly affected (Koelmans et al*.,* 2001).

Prominent pesticide families include organochlorines, organophosphates, carbamates, pyrethroids, phenoxy and benzoic acids, and triazines with varying modes of action (Kamrin*,* 1997). The varying modes of action results to different effects, many of which are chronic and often not noticed by casual observers, yet have consequences for ecological function and hence the entire food chain (Weston et al*.,* 2004). For instance, DDT, methyl-parathion and pentachlorophenol have been shown to reduce symbiotic chemical signalling of legume-rhizobium that results in reduced nitrogen fixation, reducing production (Rockets, 2007). At the same time, Pesticide poisoning can travel up the food chain causing bioaccumulation to toxic concentrations in the bodies of species high on the food chain (Cornell University, 2007; Czub and McLachlan, 2004). Rachel Carson's landmark book *Silent Spring* (1961) associated the loss of bird species to bioaccumulation of pesticides in their tissues and studies have associated reduction in bird populations, with times and areas in which pesticides are used (Kerbs et al*.,* 1999).

The environmental impact of pesticides is often greater than intended, with estimates that over 98% of sprayed insecticides and 95% of herbicides reach a destination other than their target (Ritter et al., 2002; Miller, 2004). Cases of pesticides contamination are widespread in streams, rainwater and groundwater with potential chronic effects to aquatic biota (Gilliom et al*.,* 2007; Kirui, 2006; Otieno et al*.,* 2012; Gitahi et al*.,* 2002; Weston et al*.,* 2004). The amount of pesticide that migrates from an application area is determined by the particular chemical properties of active ingredients, the distance from application site to the water body, and application method (Kellogg et al*.,* 2000). The impacts of pesticides on aquatic ecosystems are associated with the active ingredient in the pesticide and residues formed during chemical, microbial or photochemical degradation of the active ingredient. The effect of pesticide active ingredients and their degradates in the aquatic ecosystems is dependent on their chemical properties such as solubility in water, volatility, lipophilicity, degradability and particle affinity (Weston et al*.,* 2004; WHO, 2010; Denholm et al*.,* 2002). For example Aldrin, with low solubility, high volatility, high lipophilicity, high particle affinity and highly persistence in the environment could mean a high risk of impact to organisms with higher fatty tissue, especially the sediment dwelling organism (Relyea, 2009). Whereas Thiophanate-methyl with high solubility, low lipophilicity, low particle affinity and low half like, is less likely to pose more risk to aquatic biota.

The independent effects of nutrients and pesticides within aquatic ecosystems can also manifest in combination. The likelihood of combined effects is elevated since there is increased global use of both nutrients and pesticide products. These effects could exacerbate the already dire state in the water supply and distribution sectors, for example in Kenya (Box 1).

Box 1: Contamination, water supply, and distribution in Kenya

Kenya has impending challenges within the water sector in the context of water quantity, water quality and wastewater management, which remain a stumbling block to sustainable economic development in the region. Water supply remains a challenge, particularly in urban slums and rural areas where water is rationed when available if at all. Only 16.4% of Water Service Providers (WSPs) in Kenya supply water consistently (Ministry of Water and Irrigation, 2007). Given the location of the region (Sub-Sahara Africa), the climate change effects, and the seasonal water scarcity, improving the water supply is an uphill task. At the same time, water sources and catchment areas are degraded through deforestation and excessive abstraction of surface and ground water (GoK, 2003). In Kenya only 60% of the urban population and 40% of the rural area have access to safe water, with the quality of water jeopardized by increased soil erosion from the degraded catchments (UN Water, 2010; UNESCO-WWAP, 2006). The water that is supplied in these areas is turbid, has high nutrient levels (which cause oxygen depletion in lakes and water pans) and is polluted with pesticides and heavy metals. At the same time, the wastewater treatment facilities only operate at 16% of the intended design capacity, an indicator of inefficiency attributed to poor maintenance. Sewerage connection is estimated at 19% (Ministry of Water and Irrigation, 2007). The sewer transport system is no better, with only 60% of the input reaching treatment plants. The challenge gets worse considering that only 14% of the population is covered by the sewer network (Ministry of Water and Irrigation, 2007; UNESCO-WWAP, 2006). The challenges in the water sector in Kenya (quantity, quality and wastewater management) necessitate a technological and ideological shift (Council for Science and Technology, 2009).

4. Implications of contamination from fertilizers and pesticide products on current water resources policies

The effects of natural water resources contamination require robust management mechanisms through policy procedures. The UN-Water through the Thematic Priority Area (TPA) on water quality attempted to integrate water policies in natural water resources management to establish the International Water Quality Guidelines for Ecosystems (IWQGES) (UN-Water, 2014; UNU-EHS, 2014; GWSP, 2014). The aim of TPA was to monitor and report on the state of water quality, identify emerging issues and propose relevant responses while enhancing inter-agency collaboration and support to UN Member States in addressing global water quality challenges. Water Quality Guidelines (WQGs) have since been derived at national (e.g. Kenya, Rwanda, South Africa, and Ghana) or at multinational level (e.g. European Union Water Framework Directive). The Guidelines are mainly tailored based on ambient contamination status and van Dam et al. (2014) recommends that site specific WQGs need to be set up. These WQGs set the stage for policies in handling natural water quality and consequently the contamination that would result from point and difuse polution sources, such as fertilizer and pesticide residues inputs. The trends in fertilizer and pesticide pollution would definately require better policy and management approaches for most of the reagions and nations.

4.1 Water Quality Regulations in the developed regions

4.1.1 European Water Framework Directive (EU-WFD)

The European Union in 2000 recognized that Europe's water was under pressure from contamination, and an action is necessary because river basins and pollution cross borders (European Commission, 2011). The union adopted the river basin approach to manage water and associated resources, with a 2015 target of achieving good ecological and chemical status, to protect human health, water supply, natural ecosystems and biodiversity (European Commission, 2011). The directive identified already existing systems and appreciated the need to involve the public in the process since water management is linked to many policies and integration is the only way forward for sustainable water resources. Especially since a changing environment creates challenges for the future, including climate change, floods and droughts. The EU-WFD aims to protect the inland surface waters, transitional waters, coastal waters and groundwater from the deterioration in Europe and requires Member States to categorize the ecological status or ecological potential based on five classes: high, good, moderate, poor or bad (European Commission, 2011). Nonetheless, the EU-WFD needs to be transposed into national policy in every member country so that it can enter into force within their territory, presenting an implementation hurdle, despite the inter-calibration exercises by the European Commission (European Commission, 2013). Although the ecological classification schemes using the reference conditions under the WFD is deemed to integrate the emission controls with the resilience of receiving bodies from an ecological point of view, it has been heavily criticized - mainly for the term of good ecological status being misinterpreted and politicized; intergenerational transferred nutrient related pollution fears; for the inter-calibration methods to be too complex and the assessment metrics not to cover all stressors and their variability in different regions; and limited resources and capacity to implement (European Environmental Bureau, 2010). Despite the implementation and various referred to success stories (European Commission, 2011), water resources still continue to be recipients of fertilizers and pesticides, still threatening the biota (European Environmental Bureau, 2010; Ieromina et al., 2014).

4.1.2 The United States of America (USA) Clean Water Regulation

The Clean Water Act (CWA) establishes the main structure for the regulation of discharges of pollutants into waters of the United States and regulating quality standards for surface waters. The basis of the CWA was enacted in 1948 (as Federal Water Pollution Control Act) and amended in 1972 (as CWA) (US EPA, 2015). Under the CWA, Environmental Protection Agency (EPA) implements pollution control programs such as setting wastewater standards for industry and water quality standards for all contaminants in surface waters (US EPA, 2015). In compliance with Section 304(a) of the CWA, national recommended water quality criteria for the protection of aquatic life and human health in surface water is available and it includes around 150 different pollutants. The monitoring and assessment of water quality in each State are based on core and supplemental water quality indicators designated with respect to the State water monitoring strategy and designated beneficial uses of the water (US EPA, 2015). The CWA applies Total Maximum Daily Load (TMDL) approach to assess the impairment of the water body by comparing the monitoring and modeling results with the water quality standards. TMDL approach is to monitor lake, river, and estuarine water quality; identify the nature and location of polluted waters; trace pollutants to their sources; and impose controls adequate to guarantee the health of various water bodies (Boyd, 2000). Implicit in the TMDL approach is a focus on the causes and effects of pollution throughout a watershed, more explicitly though, the TMDL program will seek the identification of any and all sources of pollution (Copeland, 2012). However, the TMDL approach is limited to point sources of pollution (considered easily identifiable), while the effects associated with agricultural based non-point sources contributed to by fertilizers and pesticides are not entirely catered for (Boyd, 2000; Copeland, 2012). Boyd (2000) further states that the aproach based on ambient water quality faces political hurdles changing the inter-states politics of water quality and subsequently technical hurdles posed by watershed-level regulation and scope of interactions. Concerns on the administrative development challenges, and storm and overland water quality management have also been raised on the TMDL approach (Copeland, 2012).

4.2 Water quality regulations in Sub-Saharan Africa (developing nations)

Unlike the Water Framework Directive in Europe or the United States of America Clean Water Act (CWA), water quality standards in Sub-Saharan Africa mainly deal with the effluent discharges rather than aquatic ecosystems as a whole (GWP, 2006). The water quality legislation is not holistic and little attention is paid to larger spatial scales as a factor of poor data interpretation on assessment of water quality and inadequate systematic monitoring (GWP, 2006). In most of the countries in Sub-Saharan Africa such as Tanzania and Uganda, main policy documents on water management are in place, however detailed instructions to prevent ambiguity based on those policy documents are missing (GWSP, 2014). As such, the main challenge is the effectiveness of the water governance rather than the lack of governance arrangements. In totality, the broad failures in regulations place natural water resources (especially rivers and lakes) at a risk of contamination pressure following fertilizer and pesticides use (Alexandratos and Bruinsma, 2012). The outcome of this is tendency to eutrophication (Camargo and Alonso, 2006; Nierenberg, 2001) or possible ecosystems, biota and human population poisoning (Kortenkamp et al., 2009), for instance in Lake Naivasha Kenya (Kitaka et al., 2002; Onyango, 2012; Ndungu et al., 2013). This calls for the SSA nations not only to focus on holistic water resources policy, but also on the mechanisms to enforce the policies in a more people-involved, catchment based governance arrangements to cushion agricultural expansion and intensification.

4.2.1 Kenya Natural Water Resources Quality Regulation

The Water Act 2002 is the main policy document on managing the water resources in Kenya and it initiated an independent Water Resource Management Authority (WRMA) which is responsible for water resources management in whole country and the Water Services Regulatory Board which is authorized to issue licenses to the water service providers (GWP, 2006). The Minister for Water and Irrigation has the right to formulate and review the national water resources management strategy (NWRMS) which sets the basis to classify the water resource and determine resource quality objectives (GoK, 2002). The national water quality management strategy (NWQMS) covering between 2012 and 2016 is published as a substantial input for NWRMS. Although, the government states that the water law is fully implemented (AMCOW, 2012), WRMA is reported to be concentrated more on regulating water services and less on managing water resources (GWP, 2006). The National Water Quality Monitoring Program (NWQMP) having been running since 1982 "works" hand in hand with the Kenya Bureau of Standards and National Environment Management Authority (NEMA) using benchmarks specified for various uses as water quality standards (GWP, 2006). The tasks for water quality management among the institutions are not clearly specified creating overlaps and implementation gaps (GoK, 2011). The National Water Quality Monitoring Programme experiences challenges such as inadequate human resources capacity, inadequate equipment and financial constraints (GoK, 2011). This makes the implementation of the "well stated" NWQMP at a disadvantage, and is exacerbated by the government policy overlaps and gaps, which results to a failed monitoring scheme. Temporal and spatial fragmentation on the monitoring data and consumption statistics (of fertilizers and pesticides) enhances the potential that the agricultural activities, and expected expansion, will continue to cause water quality challenges for the natural water resources of the country. Already major catchments including L. Victoria and L. Naivasha are experiencing contamination pressures derived from intensification and expansion of the agricultural systems (IFDC, 2012; Kitaka et al., 2002).

4.2.2 Ghana Natural Water Resources Quality Regulation

In Ghana in comparison to the Kenyan case, the water quality monitoring is fully implemented and the water information agencies have been strengthened in order to obtain hydrological data with better quality (AMCOW, 2012). Ghana Environmental Protection Agency, the responsible body for introducing water quality standards and regulating discharges into aquatic systems in Ghana, reported that river water quality varies for urban and rural settlements where higher fecal contamination and biological oxygen demand are observed for the former (Government of Ghana, 1996). Mining and agricultural production are important economic activities in the country, but have been associated with the toxic chemicals contamination of the surface water (Goverment of Ghana, 2012; AMCOW, 2012). Despite the reports of a well performing water quality monitoring, eutrophication tendencies have been observed in the Pra and Birim rivers (Goverment of Ghana, 2012). The National Water Policy, approved in 2007 and "implemented", has established three out of seventeen river basins with priority to the river basins with the most serious availability, quality and environmental problems (AMCOW, 2012). However, no separate legislation is present for water quality yet and improving the human capacity is needed for further implementation of Integrated Water Resources Management (AMCOW, 2012). Ghana faces continued challenges in policy that would be importance in combating pressure related to agricultural expansion and intensification, and calls for action.

5. Conclusions and recommendations

It goes without saying that the water policies and legislations are not well equipped for the impending increases in use and application of fertilizers and pesticide products. The policies are based on ambient status of natural water quality and not equipped for potential increases. Furthermore, some of the policies in water resources protection factor less of agricultural intensification and accompanying activities. To include the potential of future dynamics, noting that water as a resource is finite, while the inputs consumption and use continues to grow, and based on the demand placed on agricultural efforts, new views need to be explored and recommended. Some indicators that could be applied in the effort to handle agricultural expansion, water resources pollution related challenges include (1) identifying pressures to natural water resources and contributing drivers; (2) employing the river basin approach; (3) set clear – ecological or chemical – status goals within timelines; (4) inclusiveness and public involvement is crucial; (5) build from already available systems; (6) integration with other policies; (7) consider potential future challenges e.g. climate change and variability; (8) cover non-point pollution sources; (9) water politics dynamics are factored; (10) multi-jurisdiction processes are considered (Copeland, 2012; European Commission, 2011; Boyd, 2000)

Table 1: Performance of water resources policies against potential indicators that would combat agricultural intensification challenges

Water resources capabilities: Well addressed (green); Fairly addressed (blue); Poorly addressed (brown); Not addressed (red)

	Indicator	EU-WFD	US CWA	Kenya Water Act	Ghana Water Policy
1	Pressures identified	Well addressed	Fairly addressed	Poorly addressed	Poorly addressed
2	River basin approach	Well addressed	Well addressed	Fairly addressed	Fairly addressed
3	Status goals and timelines	Well addressed	Fairly addressed	Not addressed	Poorly addressed
4	Public involvement	Well addressed	Poorly addressed	Poorly addressed	Poorly addressed
5	Existing baseline	Fairly addressed	Well addressed	Poorly addressed	Fairly addressed
6	Integration with other policies	Fairly addressed	Fairly addressed	Not addressed	Not addressed
7	Flexibility to include future challenges	Well addressed	Fairly addressed	Poorly addressed	Not addressed
8	Cover non-point pollution sources	Well addressed	Not addressed	Fairly addressed	Poorly addressed
9	Water politics factored	Fairly addressed	Fairly addressed	Fairly addressed	Poorly addressed
	Overall status of the policy to combat agricultural related pollution	Well addressed	Fairly addressed	Poorly addressed	Poorly addressed

While the demands on agriculture is growing, and therefore the use and application of fertilizers and pesticide products, the increases in demand and supply of the fertilizers and pesticides (Heffer and Prud'homme, 2013; IFDC, 2012; Alexandratos and Bruinsma, 2012), combined with the increased exposure of water resources to contamination as a factor of climate variability, degradation of catchments and land use changes (UN Water, 2010) are putting pressure on water resources. As highlighted in this issue paper, deterioration of water resources is eminent. A business as usual idea will negatively impact on the water resources. To bridge the gap, policy recommendations and actions resilient to the dynamics would be important and could include:

Identifying pressures to natural water resources and contributing drivers

The demands on water resources are vast in generating, boosting and sustaining economic growth and prosperity of regional economic commissions and nations through activities including farming, energy production, manufacturing, transport, tourism and recreation. On the other hand, water is at the centre of natural systems functioning and regulation. As such, the demands on water also place the natural water resources under threat of pollution from sectors including industry, households, and agricultural production. In essence, to handle the potential pressure from widespread contamination of natural water resources, policies need to incorporate a strategy to identify vulnerability to such pressures. The EU-WFD recognizes this fact stating that water resources and supply is not infinite, and value need to be attached the natural water resources, managed and protected for current and future generation uses.

Employing the river basin approach

Natural water resources are transboundary, and national or administrative level boundaries are not final frontiers. The USA CWA and the EU WFD, as regional (multi-state/national) applicable policies, outlines the need to manage the natural water resources beyond the administrative boundaries, recognizing that isolated measures to improve water quality cannot be successful without taking account of what happens upstream and downstream. To a broad level, integrated river basin management adopts a holistic approach to protecting the whole body of water, its source, tributaries, delta and river mouth through a coordinated strategy involving all the interested parties in decision-making. The integration in management of natural water resources as a concept has been widely been adopted, although Kenya and Ghana still have challenges in implementation relating to the costs, monitoring scheme and human capacity.

Set clear – ecological or chemical – status goals within timelines

Goals of natural water resources quality have been traditionally based on chemical standard. Whereas the EU WFD outlines mechanisms for classifying the status of water bodies at both a chemical and an ecological level, the USA CWA provides a broader standard based on the maximum loads that is allowable and would not affect the biota. Similar standards are applied in Kenya and Ghana, although the strictness of the standards is laxed. Moreover, water guidelines would need to have evolving standards that are time bound and adjustable based on the changing demands and contamination pressure to the natural water resources. The quality of natural water resources would in essence need improved, regular, non-fragmented monitoring schemes.

Enhance inclusiveness and public involvement in water resources protection

Public support and involvement is a precondition for the protection of waters, and for the identification of both the problems and the most appropriate measures to solve them, including their costs. Without popular backing, regulatory measures seldom succeed. The EU WFD directive recognizes this and held extensive consultations with the public and interested parties to identify first the problems, and then the solutions, to be included in river basin management plans. Although the Kenya Water Act 2002 envisions the engagement of river-based Water Resources Users Associations (WRUAs), most of them are not entirely involved in the management and implementation of water quality guidelines. As a result, the members of the WRUAs become major contributors to unsustainable agricultural intensification and as a result, water resources pollution.

Build from already available systems and databases

It is crucial that management of water resources are supported by data and becomes necessary for improved and consistent data gathering and analysis. Water policies targeting improving the quality of natural water resources needs to assess the gaps in the data streams available and make improvements by collecting systematic datasets to provide checks and balances. Except for the Kenya case which has defragmented data streams which makes it challenging to establish complete national databases, the other presented cases have fairly engaged in the success of this.

Integration with other policies

Overlapping and conflicting policies targeting the same natural water resources is a great impediment to actualizing measures to regulate the quality of natural water resources mainly since water is involved in a huge range of human activities, and therefore in the policies applied to regulate them. From agriculture, land use and development, energy generation, industrial development, and ecological flows demands, water regulation policies have great demand for “attention”, and it is important that the policies are well integrated. It goes without saying that good water management has to be sustainably integrated into all these demand areas, a factor poorly attempted by the Kenya and Ghana regulations.

Consider potential future challenges e.g. Climate change and variability

Accelerating climate variability, and economic and political dynamics require broad-based policies with the intention of cushioning the future uncertainty. Complete incorporation of this aspect, might be practical difficult, however, through assessing the pressures expected and the drivers associated with them, developing water regulations that are prepared for such outcomes could be possible. The EU WFD covers this aspect by having directive patches such as the Flood Directive, which considered the potential of climate variability affecting the flood cycles.

Cover non-point pollution sources

Overland flows and storm flows are particularly a challenge in controlling agricultural intensification based and related contamination. In regulation and monitoring regimes, these diffuse sources of pollution to the natural water present serious implementation, monitoring, and enforcement challenges. Nevertheless, the water quality problems they cause can no longer be ignored. In this context, political and legal pressures applied to the EPA, and in turn to the USA states, adjust regulatory potential contained in the USA CWA’s TMDL provisions. The ecological indicator approach under the EU WFD on the other hand, is more accommodating in monitoring such pollution sources.

Factor in water political dynamics

The nature of natural water resources such as being transboundary often brings in politics among states, regions or nations. Even within the EU WFD, despite the inter-calibration efforts, the politics of the workability and implementation of the targets have been widely criticized. The TMDL approach has also been widely criticized, with congressional politics being involved. In Kenya and

Ghana, regional politics and political regime shifts have caused great dynamism in the regulation of water resources. In the preparation of the water resources regulation therefore, the potential of the effect of the political climate and shifts is important to facilitate success.

Other actions targeting developing regions/countries

Developing nations, in addition, need to enhance the human capacity (to monitor, report and manage natural water resources), financial resources (specific to natural water resources management), and develop the social awareness in the application of fertilizers and pesticides. Trade policies on agricultural inputs also need to be revisited to avoid infinite import, through policy dialogues and multilateral agreements at regional level. At a national level, countries need to re-evaluate the water quality guidelines and align them with the natural water regulations and policies.

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