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Agri-environmental Nitrogen Policy: European Experience and Taiwan's Perspectives

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ABSTRACT

This article raises the problem of excessive reactive nitrogen (Nr) from agricultural sources – both in Taiwan and in the European Union (EU). A threat of agricultural nitrogen pollution is being addressed from the perspective of agri-environmental nitrogen policy (here: Nr policy), which is viewed as a set of governmental measures aimed at solving problems related to excess Nr in the environment. First part of the article analyses EU experience with Nr policy instruments, their implementation, effectiveness and drawbacks, while the second part focuses on the current agri-environmental policies in Taiwan which may be applied as potential Nr policy instruments in the future. Finally, the authors outline the existing gaps in nitrogen research, and propose directions for future Nr policy-related studies.

Keywords: Reactive Nitrogen, Agriculture, Agri-Environmental Nitrogen Policy, Policy Instruments.

INTRODUCTION

Nitrogen (N) is an extremely important nutrient for all living things, while nitrogen cycle is one of the main nutrient cycles on Earth. Throughout the second half of the 20th century, however, such human activities as high temperature combustion and industry, manufacture and use of chemical fertilizers, and waste disposal, almost doubled the amount of reactive nitrogen in the environment (Sutton *et al.*, 2011), which led to the disruption of nitrogen cycle beyond its safe operating limits (Rockström *et al.*, 2009). The dangers of excessive Nr in the environment (also known as nitrogen pollution) may be seen in a cascade of health and environmental impacts, such as smog and haze, acid rain, forest dieback, biodiversity loss, acidification of lakes and streams, eutrophication, stratospheric ozone depletion, enhanced greenhouse effect, and climate change (Galloway *et al*., 2003).

Agriculture, is a sector with the highest nitrogen use, where Nr is applied to the soil in the form of fertilizers used to grow crops, feed livestock and people. Over 40% of the world's

population is fed by the crops sustained by human-induced form of Nr (About The N-Print Site, 2011). At the same time, agriculture is the only source of Nr which input limits may be controlled as they represent an intended nitrogen flow – in the form of fertilizers. In other words, a proper management of fertilization practices can ensure that excessive amounts of nitrogen never enter the production system, and therefore, never result in increased Nr concentrations in the environment.

Management of agricultural nitrogen is country specific – it should take into account nitrogen excesses or nitrogen deficiency of a given state (UNEP, 2007). Galloway *et al.* (2003) suggest that for the Asian region, with its intensive agricultural sector, nitrogen management is ought to be of Nr reduction nature. Namely, in Taiwan 30.3% of the total land area is dedicated to the agricultural production (Worldstat Info, 2017), which is characterized by high yields, high level of mechanization and high fertilizer application rates. At the same time, 72% of the country's nitrous oxide (N_2O) emissions are created by the agricultural fertilization practices (Wu *et al.*, 2013). This data allows to assume that a management strategy aimed at reduction of agricultural Nr excesses is required in Taiwan's case.

Importantly, nitrogen abundance in Taiwan's agricultural sector makes it comparable to other regions/ countries, which are facing a similar problem of agricultural nitrogen pollution. Therefore, this article firstly takes a look at the EU's experience of tackling agricultural nitrogen pollution through a set of related policy instruments, which together, may be viewed as agri-environmental nitrogen policy – Nr policy. Afterwards the authors look at the current state of nitrogen management in Taiwan's agriculture and make prospective suggestions.

Nr POLICY: EUROPEAN EXPERIENCE

Oenema *et al.* (2011) define Nr policy as "a governmental plan of actions intended to change the developments in a desired direction and to solve problems related to excess Nr in the environment." It is a relatively new direction of environmental policy, having so far been developed mainly within the EU states. It is not surprising that Europe became the world leader in developing and implementing Nr policy for the past over two and a half decades, as it is the major user and emitter of Nr, with EU-27 nations producing 10% of global anthropogenic reactive nitrogen, even though the region covers less than 3% of the world's surface (EC, 2013).

EU Nr policy may be described as based on the "source-receptor" model (Fig. 1), where combustion (industries and transport), wastes (sewage) and agriculture (fertilization and livestock discharges) serve as Nr sources, while air and water act as Nr receptors (Oenema *et al.*, 2011). Therefore, divided into policies addressing various Nr pollution sources, different Nr compounds and receptors, EU Nr policy may be seen internationally as the first comprehensive approach to confront the problem of Nr pollution (Erisman *et al.*, 2011).

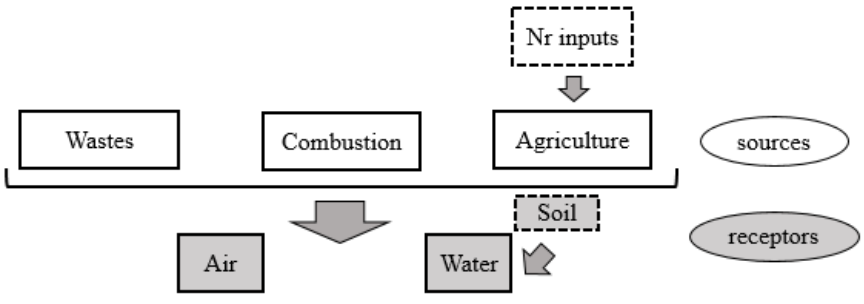

Fig. 1. «Source-receptor» model of EU Nr policy (adopted from Oenema et al., 2011)

In theory, tools that are applied to implement Nr policy in practice – Nr policy instruments – are divided into three categories: economic, communicative and regulatory (Stavins, 2001). Decision on the instrument's type or on a combination of instruments should be guided by thorough understanding of the problem, by policy objective(s), and by capabilities and decision environment of those addressed by this policy (Oenema *et al*., 2011). A graphic representation of each Nr policy instrument is provided in Fig. 2 below.

Economic instrument is aimed at encouraging desired production pathways so as to transform the actions of producers towards improved environmental outcomes for their own advantage. Generally, taxes, subsidies, tariffs and emission quotas are the most commonly used types of economic instruments (Whitten *et al*., 2003). Within the EU Nr policy, cross-compliance under the Common Agricultural Policy (CAP) may be viewed as one of the primary examples of economic instrument. It stands for a requirement that farmers in receipt of payments under the CAP are also meeting other relevant European Community (EC) legislation, related to environment, food safety, animal welfare, soil health, maintenance of the landscape, natural habitats, etc. (EC, 2017). Agri-environment schemes as governmental programs set up to help farmers to manage their land in an environmentally-friendly way are also an example of Nr policy's economic instrument (Hodge, 2003). In the UK, for instance, funding is provided to farmers and land managers to farm in a way that reduces nutrient and pesticide emissions, supports biodiversity, enhances the landscape, and improves the quality of water, air and soil (UK DAERA, 2017).

Communicative instrument within Nr policy usually includes extension services and technical assistance to farmers, as well as any other measures aimed at improvement of information flows related to agricultural practices (Oenema *et al*., 2011). EU codes of good agricultural practice, as outlined under Article 4 of EU Nitrates Directive (EU NiD, 1991), are the examples of voluntary approach within the communicative instrument, where farmers themselves consciously take necessary actions to ensure that their farming activities do not impose any adverse impacts on the environmental quality (Sutton *et al*., 2007).

Regulatory instrument, which by definition involves restrictions on the ways and methods of producer's activities (Oenema *et al*., 2011), is generally represented by pollution ceilings, fertilization limits or best available technique requirements. EU NiD is a regulatory instrument within the EU agri-environmental nitrogen policy in respect to water bodies; it provides for creation of mandatory action programs within vulnerable zones, where strict regulations on place, time, and rate of fertilizer application are imposed (EU NiD, 1991).

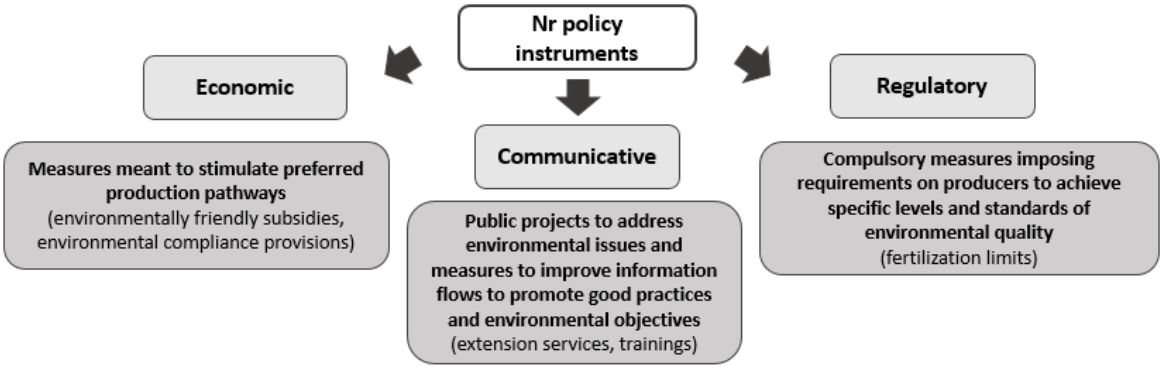

Fig. 2. Nr policy instruments

Notably, EU NiD being the most long-standing and comprehensive regulatory instrument for addressing agricultural nitrogen in water bodies, has already demonstrated its successes and drawbacks in improving European water quality, which may be considered by other

countries during their Nr policy-making efforts. Thus, Van Grinsven *et al.* (2012) note a considerable progress that EU NiD managed to achieve in decreasing nitrogen surplus in soils, modest progress in improving the quality of fresh surface waters, and a less prominent decrease of groundwater Nr concentrations in northwestern Europe. In addition to it, EU NiD four-yearly implementation reports provided by each of EU-27 member states allow an opportunity to track country-specific progress of its implementation (EC, 2013).

In sum, to a lesser or greater extent, each of the policy instruments – economic, communicative and regulatory – is being employed to address agricultural nitrogen pollution in the EU. Notably, even though these measures do not come under the umbrella of one legislation (e.g. CAP and EU NiD operate independently), they each play a role in contributing to the overall Nr pollution reduction from the EU agricultural sector. Meanwhile, however, there are obstacles pertaining to the analysis of successes and drawbacks of the existing EU Nr policy instruments. These barriers include, on the one hand, an unequal regional representation across the EU – more information on the results of Nr abatement measures being provided from the northwestern Europe as compared to Southern, Central or Eastern Europe. On the other hand, there is a visible lack of cohesive analysis on how a set of instruments operates, in other words, how a combination of all three instruments, including, for instance, EU NiD, agri-environment schemes and codes of good agricultural practice, can jointly contribute to agricultural Nr reduction in Europe.

Nr POLICY: TAIWAN'S PERSPECTIVE

Despite the fact that Taiwan's agriculture is characterized by high yields, high level of mechanization and extensive fertilizer application rates, agri-environmental nitrogen policy – as a way of agricultural Nr mitigation – is scarcely (if at all) explored. Existing research on agricultural nitrogen in Taiwan is, on the one hand, fairly abundant, and on the other hand, rather limited. Namely, a wide number of research papers from Taiwan Agricultural Research Institute (TARI) is dedicated to quantification of N_2O emissions into air and their climate change potential (Chen *et at*., 2017, Wu *et al*., 2013), as well as of nitrate and ammonia surface water and groundwater contamination risks (Chen *et al*., 2011). The lack of research on agricultural nitrogen, however, is presented through two major drawbacks. First, there is an absence of a comprehensive assessment of agricultural nitrogen management and applicability of quantitative data to the environmental policy solutions. In other words, a considerable gap exists between experimental studies of agricultural losses to the environment and their socio-environmental implications and related governmental actions. Second, current research on agricultural nitrogen management in Taiwan is conducted predominantly by various departments within Taiwan Council of Agriculture (COA) (Li, 2015 and Lai *et al*., 2013), which does not encourage an unbiased review of the current state of affairs. Though such articles can provide some valuable data, but there is a prevalent lack of critical assessment in them, preventing the understanding of current weaknesses and a need for future improvements.

In an attempt to assess the status of agricultural nitrogen management in Taiwan, the authors determined that existing agricultural policies, the nature of which may be attributed to Nr reduction and used for future development of Nr policy, include environmentally friendly subsidies and rationalized fertilization trainings as potential economic and communicative Nr policy instruments, respectively.

Thus, the latest set of environmentally friendly subsidies, as a measure to stimulate preferred production pathways (economic instrument), was established by Taiwan COA in March 2017 as "Six major farming friendly fertilizer subsidies". Their introduction became an alternative solution to the traditional fertilizer subsidies that was aimed at not only

providing financial support to farmers to help them cover the production costs, but also to guide their fertilization practices in an environmentally friendly direction. Specifically, "Six major subsidies" included transportation support for organic compound fertilizer, microbial fertilizer support, subsidy for farmland fertility improvement fertilizer and Taiwan-made organic fertilizer, free supply of winter green manure seeds, and, lastly, continued promotion of rationalized fertilization (COA Website, 2017).

Meanwhile, rationalized fertilization trainings (since 2017 – the sixth element of the "Six major subsidies"), the concept of which was initially introduced in 2008, may be seen as a measure to improve information flows to promote good agricultural practices (communicative instrument). The aim of this type of extension services is to educate farmers about the proper timing, method and rate of fertilizer application in order to increase fertilizer use efficiency, while reducing the use of chemical fertilizers and substituting them with organic compound fertilizers (Li, 2015). Rationalized fertilization demonstration sites and free soil sampling services were also established along with extension services. Taiwan COA highlights effectiveness of rationalized fertilization trainings in regards to reduction of chemical fertilizer application rates. Thus, in 2005-2007 they were 1.14 mln. ton, in the period between 2008 and 2013 they declined to 1.02 mln. ton, and in 2014 they reached their lowest of 0.972 mln. ton (Li, 2015).

As mentioned above, analysis of successes and shortcomings of environmentally friendly subsidies and trainings on rationalized fertilization, as well as of their applicability as Nr policy instruments, requires both time and visible results – in regards to the former, and an objective academic analysis – in case of the latter. Notably, no regulatory Nr mitigation measures, such as, for instance, fertilization limits or mandatory nutrient management plans (like EU NiD), are currently being practiced in Taiwan. Understanding of why Nr-related regulatory (or command-and-control) instrument is not in the arsenal of current agri-environmental policies in Taiwan may be drawn from obtaining the answers to the following questions. Is agricultural Nr pollution a recognized and persistent threat to the country's environmental health? Are Nr concentrations in the receiving bodies (here: surface water and groundwater) exceeding the designated limits? Have economic and communicative instruments been used to their full potential and proved to be unable to achieve the desired outcome? What is the level of farmers' and consumers' environmental awareness about potential Nr threats? How high is the economic dependency of farmers on fertilizer subsidies?

All in all, analysis of the perspectives of addressing nitrogen excesses in Taiwan from the point of Nr policy allows for the following observations. Firstly, there is a need for more research to be done on the social and environmental implications of excessive fertilizer inputs in Taiwan's agriculture, and for an enhanced connection between current findings done by TARI to their agri-environmental policy applications. Secondly, a comprehensive assessment of successes and failures of existing policies aimed at reduction of agricultural fertilizer inputs is necessary. Lastly, opinions of stakeholders (farmers, governmental representatives, consumers, etc.) within such an assessment are highly important in order to ensure the availability of first-hand, unbiased data. These observations evermore highlight the need for the research on agri-environmental Nr policy in Taiwan.

CONCLUSION

EU and Taiwan as, respectively, a region and a country characterized by high population density, and developed, productivity-oriented and mechanized agricultural sector, provide a curious example for a comparison study in the area of nitrogen management. Mitigation of

nitrogen excesses in the agricultural sector was analyzed from the perspective of agri-environmental nitrogen policy – Nr policy.

Thus, along with the overall successes in the functioning of Nr policy instruments in the EU (CAP, codes of good agricultural practice and EU NiD), outlined weaknesses included the need for a wider regional representation amongst EU-27 member states, and a lack of cohesive analysis on how a set of instruments, but not a single instrument, operates. Notably, in Taiwan none of the agri-environmental policies have ever been referred to as "Nr policy" and the overall Nr policy-related research is something very new for the country. Nevertheless, already existing policy measures which might potentially be used for the future Nr policy in Taiwan were specified – they included environmentally friendly agricultural practices and trainings on rationalized fertilization, as economic and communicative instruments, respectively. It was also stated that there is currently no regulatory instrument being applied in Taiwan.

In conclusion, for the future research on Nr policy in Taiwan, there is a need for:

- a better integration of qualitative nitrogen-related research with the social and environmental implications of agricultural Nr pollution;
- a comprehensive assessment and cross-country comparison on successes and failures of existing Nr mitigation measures/ policies;
- a survey of stakeholders' opinions regarding various types of Nr policy instruments in order to ensure a true representation and applicability of the data.

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