Deliverable 3.6.1: Proposals for verification of the actions in NutriTrade platform

Katarina Elofsson, Antti Iho, Lassi Ahlvik

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NutriTrade
Nutrient Offsetting for the Baltic Sea

Introduction

NutriTrade project has two broad objectives: to help improve the efficiency of national and international Baltic Sea protection and to generate a platform for voluntary nutrient offsetting. This verification report focuses on the needs of the platform. In particular, it addresses the following question: how can we ensure that the platform supports a portfolio of actions which together have a positive environmental effect at low cost.

Verification is a crucial part in any environmental protection mechanism, be it command and control regulation or cap-and-trade emissions trading. In pollution trading and offset programs the actions and their outcomes generate pollution reductions which can be traded as normal commodities. Ultimately, verification procedures should guarantee that the goods traded in the pollution permit markets are commensurate. Verification procedures are thus at the core of reliability and efficiency of any trading/offset program.

There are slightly different requirements for verification in voluntary offset programs and in programs that are part of regulatory mechanism. Put simply, in voluntary programs verification is mainly related to the general public's trust in the program in question. The more trustworthy a program is in keeping its promises, the more willing are those with actual environmental protection motives to channel their resources via the program. If trading or offsetting is part of a regulatory scheme, legal aspects become most important: the generated credits must stand court.

The NutriTrade platform is intended to match voluntary, spatially defined offsetting measures. Verification has two major components: verifying that the activity actually takes place, and verifying the (spatially defined) environmental outcomes of the activity. For the NutriTrade project, there is one more aspect that needs to be considered: defining the principles for including new, innovative measures in the platform.

This report consists of three parts: verification regarding the pilots, verification regarding new measures to be included in the platform and conclusions and practical recommendations for verification measures taken within the platform.

Verification and the Pilots

Background

Due to its pilot measures, the current project enables analyzing the verification issues with exceptional rigour. We will utilize the pilots, mussel farming, gypsum spreading and fisheries, to illustrate concretely the challenges and solution option in verifying the compliance of the agents as well as the physical effects of the measures. We will highlight these practical experiences against the existing literature on the subject.

To help compare the pilots, we will use the same structure in each of them. For any measure, the issues verification must consider are the *baselines and additionality*: i.e. would the action be undertaken without the program or not; *measurement of physical impact* on the pollution load and perhaps on ambient pollution; the *permanence* of the measure and the associated impact; *the leakage*, i.e. the secondary influences the measure could have on economy via price changes and on ecology via changes in location of pollution loads; and *moral hazard,* i.e. whether the credited actions are taken to the extend promised.

The determination of baseline, or business-as-usual activity is central in emission trading and offsetting programs. For multilateral emission trading programs, such as the EU Carbon Emission Trading System, this is managed through the issuing of emission permits, by grandfathering or auctioning. Difficulties are larger in situations with bilateral trading, such as under Joint Implementation or the Clean Development Mechanisms, where it is necessary to define the amount of emissions that would occur now and in the future in the absence of bilateral trading and offset markets (Michaelowa et al., 2003). Only then is it possible to quantify the additional emission reduction for which offset compensation is paid, i.e. the additionality of a project.

The measurement of the impact of offset measures on nutrient load to the Baltic Sea is of central interest. By comparison, the measurement of carbon emissions is a straightforward issue, as the amount of carbon is proportional to fossil fuel consumption. Quite different, the impact of many agri-environmental measures on the environmental variable of interest, such as nutrient loads to the Baltic Sea, or biodiversity, is typically hard to measure (Elofsson, 2003; Wätzold and Schwerdtner, 2005). The reason is that the link between the activity which is subsidized and the corresponding environmental impact is associated with considerable uncertainty.

The issue of permanence of a measure is often discussed in the context of carbon trading and offsetting. The question is then whether a measure undertaken implies that the pollutants which are, at that point in time, removed from the system will stay removed, or if they will eventually return through some adjustment process in the environment or the economy. For example, if more carbon is stored in forests, this storage may be temporary in nature, as more forest could be harvested later on, and the natural release of carbon could increase (Kuikman et al, 2011).

Within the area of carbon trading and offsetting, the issue of leakage has received high attention, given the risk that a stringent policy in one country, and hence large abatement efforts, can imply incentives for other countries to free-ride, taking advantage of the efforts in the first country and doing less in their own countries.

The final aspect of verification is the moral hazard aspect, i.e. the risk that those contracted to carry out the abatement involve in opportunistic behavior, which jeopardizes the intended outcome of the project. This could involve actions which a both legal but unwanted, as when abaters take advantage of their market power, and actions that are illegal, such as false reporting and other type of cheating (Michaelowa et al., 2003; Ozanne et al., 2001; Moxey et al., 1999).

Mussel farming

Baselines and additionality

In the case of mussel farming in the Swedish part of Baltic Sea, the determination of a baseline is at the moment a rather simple issue, as mussel farming is not commercially viable and hence mussel harvesting has additionality wherever it is undertaken. The mussel farms which are in place are funded by different combinations of public and research funding. The same is likely to hold for other countries around the sea. This is a clear advantage from the verification side of the problem, but a problem from the economic side, as it means that offset schemes need to compensate a large share of the costs for mussel farming, making the measure a less cost-efficient one. Within the near future, it is however possible that a market for animal mussel feed will develop. This could entail more sustainable livestock management compared to now, but also that a smaller share of the cost needs to be covered by the offset mechanisms. It would also imply that it becomes more difficult to determine baseline mussel farming by different firms as well as in total. In the beginning of the development of such a market, it is likely to be partly publicly funded, which can further complicate the picture with regards to baselines. For the near future, mussel farming can thus be seen as a measure with general additionality.

Measurement of impact

Mussel farming has the advantage that the impact on the Baltic Sea nutrient status is relatively easy to measure. Mussels contain about 0.64-1.02% nitrogen and 0.04-0.06% phosphorus (Persson, 2004). The nutrient content of a particular harvest can be evaluated with relatively high certainty using a small sample of the harvest, e.g. one kilo, and analyzing the contents in a laboratory, if higher certainty is wished for.

Mussels can have local impact on water quality. The effect can be both positive, implying clearer water and improved spawning conditions for fish, or negative, due to the accumulation of substances right below the mussel farm. The direction and magnitude of the impact depends on the locally specific conditions. At this moment, it is not well known whether this local effect is so large, that it is worth to devote efforts to analysis thereof within a nutrient trading of offsetting scheme.

Permanence

When mussels are harvested, nutrients are removed from the sea. If the mussels are subsequently used as animal feed, or as a high-quality fertilizer on arable land, some of the nutrients will in fact return to the aquatic environment and hence to the sea. However, when used as feed or fertilizers, the mussels will, simultaneously, replace nutrients that would otherwise have been added to the aquatic environment through purchases and use of imported feed and imported artificial fertilizers. Hence, there is likely to be a relatively high permanence of the effect of mussel farming.

Leakage

This issue of leakage for nutrient offset schemes in the Baltic has at least two aspects. The first is that increased production of mussels to be used as feed and/or fertilizer could have a temporary negative effect on the international prices on these products and therefore increase their use in other parts of the world. This can have negative effects on the environment if the increase occurs in environmentally sensitive locations. We judge that this effect will be both small and of short duration. The second leakage aspect is that for a voluntary offset market in general. The development of a strong voluntary offset market, where abatement activities are purchased by private firms and individuals, could potentially imply that public bodies and governments reduce their abatement effort in response. Whereas this type of leakage is relatively extensively discussed in the literature, there is little knowledge on the possible size, and actual existence, of such leakage. This type of leakage is therefore usually not considered when developing voluntary or public nutrient offset schemes.

Moral hazard

There are several circumstances of relevance for mussel farming. For example, at the time that the mussels are harvested it is not possible to know when the mussel farming has started, or if they origin from the contracted location. That can be hard to evaluate when the mussels are landed. Measuring the harvest at the time of landing will at least reduce this uncertainty to the buyer. An alternative to measuring the harvest at the time of landing would be to base the compensation on a sales receipt, if the mussel farmer has sold the mussels to a feed factory or to a farmer as fertilizer. In the feed factory case, there is a higher risk that the mussels originate from another location and firm than the contracted one. They could even originate from the Swedish west coast or Denmark, where mussels are commercially viable, as they are sold for human consumption. In the short term, measurement at the time of harvesting seems to be the only feasible option if one wishes to have high certainty of compliance. However, mussels are heavy to transport and this reduces the likelihood that it is economically viable to transport mussels across long distance. Hence, requiring receipts from a feed factory can provide reasonable security, even though it might not completely remove the risk of opportunistic behavior.

The degree of moral hazard is closely related to the choice of design on the compensation. Mussel farming is subject to production uncertainty, as the harvest is determined by weather and local-specific conditions for the farms. (Notably, there is evidence from the Swedish west coast, that this uncertainty is smaller for experienced mussel farmers.) Hence the mussel farmers would prefer compensation which is based on their investment and operation costs, rather than the output. However, that increases the risk that the mussel farmers put little effort into the management and harvesting of the mussel farm, where in particular the harvest can be a costly operation. An alternative is to base the compensation on the quantity of harvested mussels. The disadvantage with the latter approach is that the potential mussel farmers will be less inclined to get involved in such contracts, because they have to carry more of the risk. The mussel farmer can compensate for this by demanding a higher compensation, which partly solves the problem, but the large risk to the mussel farmer is still likely to imply that small mussel farmers will be less interested in getting involved in offset contracts. Experience from nutrient trading schemes in the USA, discussed during the NutriTrade workshop in Helsinki 16-17 May 2016, shows that farmers are not willing to trade nutrient offset measures when the trade is associated with an economic risk. This suggest that a compensation scheme which at least balances the risk of mussel farmers against those of the voluntary platform would be optimal from an environmental and economic point of view.

There can also be other types of opportunistic actions, i.e. claiming an extremely high price in the hope that the number of bidders will be few. This can be counteracted by setting a reserve price, i.e. a maximum compensation which is unknown to the bidders, to ensure that the compensation is reasonable in relation to the environmental benefits achieved. Such a reserve price can be based on existing knowledge about the costs of reducing nutrient loads to the Baltic Sea by measures currently implemented through various policy schemes.

Gypsum pilot

Gypsum treatment of particularly clay fields may lower agricultural phosphorus loading entering the Baltic Sea. The abatement effect of gypsum has been assessed earlier in laboratory studies (Anderson et al 1995; O'Connor et al 2005), field trials (Uusitalo et al 2012) and in a pilot where an area of about 100 hectares was treated with gypsum (Ekholm et al 2012). The latter reported catchment level reductions in DIP loading by 29% and in PP loading by 57%. The economic efficiency of gypsum treatment has been evaluated by Iho and Laukkanen (2012). All these studies suggest that gypsum is able to markedly and efficiently reduce both DIP and PP loading from surface and subsurface runoff. NutriTrade organizes a large-scale gypsum pilot which involves 55 farmers applying gypsum to part or all of their field parcels, on about 1500 hectares altogether. The pilot takes place in Savijoki river basin, South-West Finland.

Baselines and additionality

Finnish agri-environmental program does not compensate farmers for spreading gypsum. On the other hand, gypsum as a product to improve soil structure has been on the markets for a while. It has also been suggested to be used in preventingt the potato desease *Phytophthora infestans* (see, e.g. Messenger-Routh et al 1996; Maloney et al. 2005). The application of gypsum in Finland thus far has been nevertheless minimal. Therefore, one can quite safely state that the measure is almost fully additional.

Measurement of impact

The absolute abatement always depends on the initial levels of phosphorus loading which vary strongly from one field parcel to another. Previous catchment level experiment suggested that DIP abatement was as high as 29% and PP abatement as high as 57%. One of the targets of the pilot is to provide more precise results on long term effect of gypsum treatment in large catchments.

The treated area is hydrologically uniform and the effects on the nutrient loading in river Savijoki are systematically monitored for at least three years after the treatment. The area also has a good measurement data from the preceding years. Furthermore, one sub basin is left as an untreated control area. It's nutrient runoff will be monitored with the same precision as the treated area. That is, gypsum pilot has extensive load measurement before and after the treatment, on the treated area as well as on the control area.

The pilot also assesses the effects of gypsum on local aquatic biota (such as mussels) and on agricultural soils.

Permanence

Gypsum improves the ionic strength and structure of the soil, reducing erosion and dissolved phosphorus runoff. According to previous experiences, gypsum dissolves rather quickly to soil. The effect occurs immediately and can last up to 4-5 years. The soil samples will provide additional information on how long the effects last. As soil phosphorus is the key driver of leaching of dissolved phosphorus, the pilot includes monitoring on the development of treated agricultural soils. The key items to be followed are the level of potentially plant available soil phosphorus, sulphate concentration and the ionic strength of the soil solution.

Leakage

The gypsum (calcium sulfate dihydrate) is a by-product of phosphorus fertilizer production and has so far had no commercial value. Over the decades, gypsum has simply been piled as a massive mountain close to the Siilinjärvi apatite mine and the fertilizer company running it (YARA). Gypsum is produced 1,3 billion tons annually. Apatite source in Siilinjärvi is magmatic and thus it is free of heavy metals and safe to use in agriculture.

Moral hazard

There are certain well identifiable steps in gypsum treatment: placing the order, having the gypsum delivered to correct field parcels in correct quantities, and its appropriate application. The pilot verifies each of these either directly or indirectly. Farmers have been committed to the gypsum treatment with signed agreements, in which the parcels to be treated are defined. They order the gypsum from agricultural store, which subcontractor, a transportation company delivers the gypsum to farms, usually directly to parcels. When gypsum is delivered the gypsum should whether spread or stored. Since the gypsum pile requires land area or storage place, farmer is willing to spread the gypsum as soon as possible. The gypsum treatment costs and required time is compensated for the farmer when the work is done.

Fisheries pilot

Fisheries pilot is based on the idea of removing nutrients via removal of fish with low commercial value, such as cyprinid fish. Moreover, the pilot aims at increase the utilization of cyprinid fish for human consumption and to restore the cyprinid populations closer to their natural levels. The parts that are not suitable for food production, can be utilized in other ways, such as in animal feed production. The mechanism takes the form of subsidy for “ecosystem services”, that is the phosphorus uptake by removed fish. Long-term aim of the project is to create permanent demand for cyprinids, making fishing sustainable also without subsidies.

Baselines and additionality

If removal fishing would take place even without subsidies, the pilot would not be “additional” and it would have no environmental effect. At the moment cyprinid fishing is not commercially viable, and therefore additionality is not an issue for this pilot: the natural baseline would be no fishing of cyprinids without subsidies.

However, this situation might change if the demand of cyprinids would increase and raise the market price.

Measurement of impact

In principle, removal of cyprinid fish has a threefold impact on nutrients. The direct impact refers to the amount of nitrogen and phosphorus that is uptaken by the removed fish. Nutrient content of cyprinids is rather well known (Iho et al. 2016 use 0.75% for the average of bream and roach), so the uncertainty regarding the impact given the biomass of cyprinids is relatively low. However, there are two indirect impacts that are more difficult to measure. First, if used for human consumption, fish will replace other protein consumption, partly meat produced in the Baltic Sea catchment. If used for animal feed, fish replaces other nutrient input to the system. Therefore, if cyprinids are used for human consumption, they will have an indirect positive effect on nutrient abatement. Second, a large-scale fishing of cyprinids can have effects on ecosystem and food-webs; as an example of a human-induced changes in food webs see Lammens (2001), Olin et al. (2006), Österblom et al. (2007), Setälä et al (2012), Iho et al. (2016).

It will be difficult if not impossible to accurately measure these indirect effects, but both of them are likely to be positive and small relative to the direct effect. Therefore, only considering the direct effect in calculations can be thought of a conservative estimate of the true impacts of fishing.

Permanence

A portion of the removed nutrients are likely to end up back to the Baltic Sea. If the fish is used for human consumption, however, this effect is negligible in cities with advanced wastewater treatment facilities, and also insignificant in scattered settlements. If the fish is used for animal feed, it will not go through any treatment processes and a larger share of nutrients will leak back to the sea. All in all, permanence cannot be considered an important issue for the fishing pilot, especially if the end product is human food.

Leakage

There are two aspects of leakage that need to be addressed. First, in the context of management fishing, the issue of leakage could be related to fishermen, who had been fishing another type of fish with positive environmental effects, switching to cyprinids because of the subsidies. Therefore, such subsidies may "crowd out" other fishing and the true environmental effect may be somewhat overestimated. It is commonly viewed that cyprinid fisheries as triggered by the project is additive for fishermen: the landings of other fish species will not be affected. It would be interesting to verify this by looking at the fisheries before and after launching the subsidy. This could later be answered with the help of comprehensive harvesting data. Second, the management fishing based on voluntary offsetting may crowd out other public policies. This problem is, however, common to all projects under voluntary trading, and not specific to the fishing pilot.

Moral Hazard

The regulator cannot observe fishing efforts, only the catch, which may create a moral hazard problems. In particular, this is the case if the aims of the fisherman and regulator conflict. The extent of moral hazard problems depends on the chosen instrument; in case of subsidies that are paid per biomass, the fishermen has the same incentives as the regulator would have. It follows that the regulator only needs to verify the size of the cyprinid catch, and there is no need to monitor fishing effort. Note, that an opposite would hold if the policy instrument took the shape of a fixed lump-sum fee.

Summary on the verification issues around the pilots

The following table collects the key issues related to verification. It states whether verification is ambiguous, simple, expensive, etc; and makes a few notes related to these particular measures

Table 1. Verification issues on the project pilots

	Baseline	*Impact*	*Permanence*	*Leakage*	*Moral hazard*
Mussel	Simple/no prevailing activity	Easy to measure, certain, direct nutrient removal.	No, or environmentally beneficial effects of mussels after harvesting.	Not an issue unless mussels are commercialized on larger scale.	Easy to observe
Gypsum	Simple/minimal prevailing activity	Doable, transferability of the results an interesting issues	Lasting effect, duration must be measured once carefully, then extendable	Not an issue	Relatively easy to observe
Fisheries	Depends on market prices, with low prices simple: no activity	Direct effect simple, potential food-web effect difficult to measure (academic literature suggest positive effect)	Nutrient removal effect starts and ends with landings. Food-web effect may be longer. Removal of cyprinid fish might improve the buffering capacity of the food web towards nutrient loading.	?	Landings easy to observe. If cyprinid stock would be the desired target, this would be difficult

Verification regarding new measures

Next we propose baselines for inclusion of any new innovative measures to the nutrient trading. Easily observable measures whose effects can be reliably estimated and verified are, naturally, the most preferable ones. However, only focusing on measures having these properties limits the potential for nutrient trading. Verification of new, innovative measures is a delicate balance of potential for nutrient trading on one hand, and ecological uncertainty as well as a need for costly enforcement on the other.

Even if credits fail to be created due to natural variability or technical uncertainty about the effectiveness of the measure, the regulated sources are still liable for complying with the regulation. This may hamper the interest of cautious point sources to trade or offset nutrients. Regulator can then respond by: (i) considering which abatement measures to accept for credit creation, (ii) providing risk management services, e.g. by credit-insurance pools or serving as a creditor of the last resort.

Measurability

The ultimate aim of regulation is to meet the water quality goals; therefore it is vital that abetment measures used in nutrient offsetting have a real effect on water quality. In some cases, in particular for point sources, it is possible to estimate the true effect of the measure very precisely. However, for most non-point sources, measurement of the true effect is not possible. Scientific research from field-tests, or trustworthy and accurate scientific models can be used to estimate the nutrient reduction. Last, there is a set of measures whose effects cannot be measured and there is not enough knowledge on the true effectiveness.

Measurable projects

Projects whose effect can be measured, such as point-source abatement measures or targeted fishing, can be easily incorporated in trading even if their effectiveness is not perfectly known beforehand. These measures would produce offsets based on the materialized (measured) effects. These measures include, for instance, targeted fishing as it is possible to calculate the total phosphorus removal based on the phosphorus content in the fish catch. Moreover, measures in wastewater treatment plant belong to this group as emissions from treatment plants are routinely measured and reported.

Non measurable but extensively studied projects

Projects that are not measurable, but whose effects can be reliably estimated based on the literature or models, can be included as part of the trading scheme. Such measures include wetlands, catch crops or reduced tillage. The credits created by these measures can be based either on an extensive meta-analysis, combining a large set of results from the literature, or models such as INCA-N or ICECREAM -models. This is a standard practice in existing trading schemes where trading with non-point sources is allowed, these including in Lake Taupo, South Nation River or Virginia Nutrient Trading Schemes (See deliverable on literature review).

Non measurable and imperfectly known projects

In the last group, there are innovative projects with high potential but technical uncertainty about their effectiveness. The advantage of nutrient trading is that it creates incentives for innovation and therefore it should not entirely neglect these new innovations. In theory, field testing of these measures could be funded by crowd funding as a part of the voluntary nutrient trading for measures that are judged to have a high enough potential. In that sense the platform could take the role of the Baltic Sea Action Plan Fund. However, these uncertain projects cannot be used to create credits and cannot be used to offset emissions elsewhere, as their true effect cannot be guaranteed.

Compliance

If measures are not perfectly observable, the participants in the scheme may have incentives to cheat. In order to ensure that participants comply with the rules, there may be a need to carry out costly enforcement actions, such as regular field visits. We divide projects into three categories: (i) observable measures, (ii) unobservable measures without incentives to cheat, and (iii) unobservable measures with incentives to cheat.

Observable measures

The effort of certain projects is fully observable and hence fully enforceable. Examples abound, these including investments in point sources, wetland and permanent changes in land use.

Unobservable measures, no incentives to cheat

Another class of measures is where the effort is unobservable, but the regulator observes some part of the implementation process, which is enough to guarantee that cheating does not take place. As an example, consider gypsum amendment where the regulator can ensure that the product is delivered to the farm, but cannot ensure its application. However, once the gypsum is delivered to farmers, it is privately optimal for them to spread it. Hence, the incentives of the regulator and the farmer are aligned. Such measures could be used to generate nutrient credits.

Unobservable measures, incentives to cheat

Last, there are measures that are potentially effective, but cannot be observed without routine field inspections. As an example, consider reduction of inorganic fertilizer use: In theory a farmer could be compensated for the reduced yield, but in practice farmer's application of fertilizer is impossible to observe and therefore regular soil measurements would be required.

Table 2. Examples of nutrient abatement projects of different categories

	Observable	*Not observable, no cheating*	*Not observable, cheating*
Measurable	Investment in WWTP	Mussel farming, management fishing	

Non-measurable, studied	Wetlands, Sedimentation ponds, Reduced tillage, Set-aside	Gypsum amendment	Reduced fertilization, Manure spreading
Non-measurable, not studied	Artificial oxygenation	Nutrient separation from manure	Aluminium treatment of waters, Nutrient removal from seabeds

How to address these issues

Verification ratios

Costly field inspections are required for non-observable measures for which cheating can be an issue. One way to address this problem is to set a “verification ratio”, that is, an additional ratio that is paid in top of the credit price and used to cover the expenses of verification, such as field inspections. This ratio would only apply to measures where non-compliance is a problem and it would thus discourage implementation of these projects.

The cost of field inspection has varied from 40 Euros if carried out by other farmers, to 300-600 Euros if carried out by experts. Let us assume that a farm offers measure with annualized cost of 500 Euros. If field inspection costs are 300 Euros or 600 Euros per visit, the verification ratios would be [1]

1.60-2.20 if the measure requires annual visits

1.13-1.27 if the measure requires visits every five years

1.07-1.15 if the measures requires visits every ten years

1.03-1.06 if the measure requires visits only once

[1] A discount rate of 4 % is assumed throughout these calculations

Credit insurance pool

Natural stochasticity may preclude formation of credits. This may be a particular problem for targeted fishing or mussel cultivation where natural conditions may prevent a high enough catch. One way to address this problem is to set a reserve ratio, which sets aside a certain proportion of created credits in a credit insurance pool. This pool would then be used to produce the missing credits during bad years, and reduce the annual variability and the risk of exceeding the environmental (or regulatory) targets. The reserve ratio could be set for credits created by any projects, for those generated by non-point sources or only for those where natural uncertainty is an issue. In Pennsylvania, a reserve ratio is 10 percent for all the generated credits. In West Virginia, a reserve ratio is 10 percent for credits generated by point sources and 20 percent for non-point source credits.

True-up period

After the compliance period, the regulated sources may end up in a situation where they have not met the regulatory requirements, for instance due to delays in investments or natural stochasticity in credit creation. For flexibility, the sources can be given a "true-up" period. This is a designated period during which regulated sources can finalize credit purchases after the compliance period.

Recommendations

Verifying actions vs outcomes

Generally, basing payments (here: abatement credits) on measured outcomes instead of actions can bring about great efficiency gains. With modern modeling and monitoring tools, units could be defined in terms of pollutant loads, both point and nonpoint. Such approaches can improve cost-effectiveness (Ribaudo et al., 2014). For verification, this poses a challenge. Essentially, there is a trade-off in where the uncertainty manifests itself, and how costly it is to reduce this uncertainty. If verified units are determined in terms of actions, we have to face uncertainty in the links between the actions and outcomes. For point sources, it is obvious that verification is based on measured reductions instead of actions. For non-point sources monitoring the outcomes brings about uncertainty in terms of the links between the actual actions and the observed effects in the nature, which are strongly influenced by natural stochasticity.

But even for point sources, there is always some modeling involved: not all emissions get monitored but instead statistically estimated from frequent samples. For verification purposes, we must strike balance between the costs from monitoring outcomes and uncertainty in monitoring actions.

Clean development mechanisms have standardized their verification procedures. If nutrient trading is to be included in regulatorily binding environmental protection, verification practices in CDM offer a great benchmark for the developers. For efficiency gains to be realized as net gains, the cost savings generated by more efficient allocation of measures must be higher than those allocated to administration. Verification efforts done for the CDM projects can be used when assessing the costs of verification if aiming for a large scale nutrient trading as part of official regulation. For analysis on CDM verification, see for instance Magnusson (2015).

A note on agricultural measures

Like for any other measure, including agricultural measures in a trading platform would require their verification. The U.S. examples show that by using models that predict the outcomes of the measures, such measures could be technically accepted in a trading scheme. Also, the issues of uncertainty could be tackled by using trading ratios that would put more weight on certain, measurable reductions than those based on model calculations. In the EU area, however, the common agricultural policy (CAP) hinders the adoption of agricultural measures to any voluntary trading schemes or mechanisms. In Finland, for instance, about 90% of farmers and farmland is included in the agri-environmental scheme of the CAP. Because farmers are not allowed to be double compensated for any of these measures, and because there is limited amount of reliable measures from agriculture, there is very little room for voluntary mechanisms.

Another important point is related to unintended effects of most conservation measures aiming at phosphorus reductions. Literature unambiguously shows that most of the measures aiming at reducing erosion increase the loading of dissolved phosphorus (Dodd and Sharpley 2016). The ranges of estimates, however, are extremely large. Furthermore, as by definition the dissolved fractions of phosphorus are fully available to algae in receiving waters, only a fraction of particulate phosphorus is. Unfortunately, the literature is ambiguous as to the fraction of PP that is eventually algal available (see e.g. Uusitalo et al. 2000; Ekholm and Lehtoranta 2012).

This is problematic for verification: what models to choose when defining the eutrophying unit of phosphorus for any measure? There are "safe" measures, such as spreading gypsum or lowering the soil phosphorus status, but for any new measure, the amount of background research for verification would be very costly, and potentially uncertain.

Table 3. Ranges of effects of some agricultural conservation practices on particulate and dissolved phosphorus (Dodd and Sharpley 2016).

Abatement measure	*Abatement per cent, particulate phosphorus*	*Abatement per cent, dissolved phosphorus*
Conservation tillage	-33 -- 96	-308 -- -40
Constructed wetlands	47 – 70	-72 – 94
Buffer strips	35 -- 96	-258 – 88

Table 3 gives a concrete picture of the ambiguities related to particulate and dissolved phosphorus reduction. A negative number means that the measure *increases* the loading of the phosphorus fraction. first of all, the ranges are unacceptable high. Second, all measures might be substantially increasing the loading of the dissolved fraction, which is 100% algal available and thus much more harmful than the particulate fraction.

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