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Precision farming (site-specific management)[1]

1 Measure definition

Precision farming or precision agriculture is an approach that applies appropriate management practice at the place and time where and when it is needed, adjusted to spatial and temporal variability of crop and environmental traits over farm areas and small-scale heterogeneity of soil conditions (Finger et al. 2019). It is a technology intensive practice assisted by GIS technologies, considering site-specific sensor information of nutrient status, soil moisture, and other soil properties (Roy and George 2020). Management practices include controlled traffic farming during tillage and harvest, adjusted site-specific application of inputs such as nitrogen and pesticides (Balafoutis et al. 2017), and precise seeding and irrigation. Precision farming is often combined with zero tillage systems on large farms (Finger et al. 2019).

Geographical and biophysical applicability

- **Suitability to different biophysical conditions:** Precision farming is independent from biophysical constraints; it can be applied on any field where machinery is typically used. Steep slopes or very small patches may not be suitable.

- **Suitability in EU/German conditions:** Site-specific management relies on processing sensor data by GIS technology on heterogeneity over fields and farms. Beside the willingness of farmers to deal with new information technology, these processes require power supply and access to internet or satellite connection (GPS). In Germany and other European countries, companies offer services for field data collection by scanning the field and data interpretation, thus making precision farming more accessible for farmers. Main adopters until now are mainly large-scale conventional farms, but site-specific fertilizer management and irrigation or precise seeding and harvesting can be suitable for organic agriculture or application on smaller field sizes.

Fit with NbS definition

Precision farming does not rely on natural processes or mechanisms, and is therefore not a nature-based solution as defined in the working definition for this research project in Reise et al. (2022), but rather technological-based to reduce external input and impact on field-scale.

However, precision farming can lead to improved environmental impact of agriculture by enabling small-scale adjustment in application of fertilizer or pesticides and thus reducing the impact on the environment, including nitrate leaching, gaseous emissions (N_2O), and fluxes of pesticide residues to water bodies (Balafoutis et al. 2017). The reduction of nutrient and pesticide excess along the sites of the croplands and buffer strips may promote wild plants that are adapted to lower nutrient availability and targeted pesticide application can reduce negative impact on beneficial insects.

[1] This factsheet was developed as part of the research project "Naturbasierte Lösungen (NbS) im Klimaschutz: Marktanreize zur Förderung klimaschonender Bodennutzung" (FKZ 3721 42 502 0) and is also published as part of the Annex to the UBA report "Role of soils in climate change mitigation", see www.umweltbundesamt.de/publikationen/Role-of-soils-in-climate-change-mitigation.

Despite its potential to be applied in a more environmental suitable way (Roy and George 2020) precision farming is up to now typically part of large farms with highly intensive management systems that rely on high levels of inputs of fertilisers and pesticides, e.g., zero tillage systems.

2 Mitigation Potential

2.1 Carbon sequestration

A site-specific N-fertilizer application across a field, i.e., the reduction of overfertilization and supplying enough fertiliser where needed, taking into account soil heterogeneity and N availability, could be a way to increase the carbon stock in the soil by reducing soil respiration (Khan et al. 2007) while maintaining crop root production and C input to the soil.

2.2 Total climate impact

Controlled machine guidance and traffic farming can lead to an optimization of fossil fuel consumption due to limited overlap in farm operations, resulting in a reduction of up to 6% of fuel use (Shockley et al. 2011).

The site-specific adjusted management is more efficient in the use of fertilizers, seeds, and pesticides; e.g. the use of herbicides can be reduced by site specific spraying ranging from 11% reduction in herbicides for broadleaf weeds in maize to 90% savings of herbicides for grass weeds in winter cereals (Balafoutis et al. 2017). This also reduces the indirect energy consumption footprint from such inputs (Finger et al. 2019).

The precise nitrogen fertilization reduces nitrogen losses such as ammonia and N_2O-emission by up to 34% (Sehy et al. 2003).

2.3 Limitation on the mitigation potential

Like in all technologies, when responsibility is transferred from persons to algorithms, precision farming depends greatly on the way of usage and the modelling / programming behind the application. Small changes in the modelling can increase the use of fertilizers above the needs, thus drastically limiting its potential of mitigation and reducing GHG.

3 Adaptation and co-benefits

- **Weed control:** Camera based automatic mechanical weed control can reduce herbicide use (Zimmermann et al. 2021).
- **Costs:** Reduced traffic by precise machine guidance can result in a 25% reduction of expenditures for fossil fuels (Jensen et al. 2012).
- **Environment and biodiversity:** Site-specific pest control reduces pesticide residues in the environment, e.g., contamination of water bodies or fallows and natural habitats of insects (Balafoutis et al. 2017).
- **Yield:** Site-specific fertilization rate and precision harvesting increases the potential to meet quality standards in wheat (Morari et al. 2018). The yield shows greater uniformity over the field area (Diacono et al. 2014).

- **N** management**:** Site-specific N fertilization according to field heterogeneity can reduce nitrate leaching (Delling and Stenberg 2014).

4 Trade offs

- **Herbicide use:** Precision farming is as of now often used in combination with no tillage practices (Jensen et al.2012), that require a higher usage of herbicides to control weeds. Thereby it is perceived as a technique designed to enable intensive land use and promote herbicide use.
- **Costs and availability of technology:** This technique requires information of environmental sensors or field data collection. Diagnostic tools or access to remote sensing data might be not available for everyone or cost intensive.
- **Data management and security:** Data management can be complicated and a security issue for farmers. Big data sets can increase the vulnerability of users and their dependencies from companies.

5 Implementation challenges

Precision farming requires tools, technical understanding and big data sets on the field sites that might be difficult and costly to obtain and maintain. The interpretation of the data and implementation of site-specific management can be challenging for farmers. It is mostly applicable to mechanized and large-scale agriculture (Finger et al. 2019). There is concern that precision agriculture simply supports further intensification of yields, without absolute reductions in the intensity of management and without reducing negative environmental impacts. The approach has been criticized for increasing the dependency of farmers on input suppliers and data industry, without necessarily delivering sufficiently on environmental and social objectives (Duncan et al. 2021).

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