Sustainable intensification of crop production

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Relevance

Concerns about the environmental impact of farming has increasingly been the focus of discussions in the EU. Croplands, a primary land use in Europe, have a significant **impact on the environment** (soil, water bodies, global climate, local biodiversity and human health). The use of fertilisers and pesticides associated with conventional farming may lead to pollution and/or climate change. There is a continuing decline of farmland biodiversity (e.g. the Farmland Bird Index declines throughout the EU). The growing share of organic arable farming and organic food consumption shows that consumers are increasingly concerned about conventional agriculture.

Why would anyone then consider intensifying conventional arable farming further? Why would you inflict further problems to the environment? The comforting answer is that a resource efficient, technological smart pathway exists.

Why is improved cropland management important?

Substantial untapped climate change mitigation potential exists in the arable farming (crop production) sector. Improved cropland management can contribute to climate change mitigation, and furthermore, result in additional biomass production. This additional biomass in turn may be used for bioenergy production, leading to supplemental climate change mitigation. As Tilman et al. (2011)[1] put it; "attainment of high yields on existing croplands of underyielding nations is of great importance if global crop demand is to be met with minimal environmental impacts".

There is a substantial yield gap in Central and Eastern Europe, as well as in many other parts of the world. Actual yields are far below the potential. These **unproduced crops represent wasted opportunities**. If land would be more efficiently utilised, more food, feed, fibre as well as fuel (energy) could be produced on the same amount of land.

Conventional agricultural production is usually associated with increased burdens on the environment, due to advanced use of inputs such as fertilisers and pesticides. Intensive use of agricultural inputs, however, is not the only way to arrive at larger harvests. Intensification can be done in a sustainable way. Responding to the environmental pressures of arable farming, Mueller et al. (2013) argue that there is increasing focus on 'sustainable intensification' as a means to increase yields on underperforming landscapes while simultaneously decreasing environmental impacts[2]. FAO (2011)[3] presents sustainable crop production intensification as a new paradigm.

Definition of sustainable intensification of crop production

Sustainable crop production intensification can enable the production of more food, feed, fibre and fuel with fewer resources, i.e. by increasing yields per unit of land (and often also

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[1] Tilman, D., et al. (2011) Global food demand and the sustainable intensification of agriculture. Proc. Natl Acad. Sci. USA 108, 20260–20264

[2] Godfray et al. (2010) offer sustainable intensification of agricultural production as a way forward. Tscharntke et al. (2012) use the term agroecological intensification.

[3] FAO (2011): Save and Grow. A policymaker's guide to the sustainable intensification of smallholder crop production

unit of water or fertiliser). Sustainable intensification means in short: enabling farmers to grow more with less, i.e. to produce more food, feed, fibre, and fuel while using less water, land, energy, and other inputs, thus improving resource efficiency in farming with the help of clever technology. Smith (2013)[4] defines sustainable intensification as "the process of delivering more safe, nutritious food per unit of input resource, whilst allowing the current generation to meet its needs without compromising the ability of future generations to meet their own needs". As the Sustainable Intensification Platform[5] in the UK puts it, 'intensification' should not be confused with 'intensive' farming. Sustainable intensification of crop production does not assume a shift from less to more intensive modes, or vice versa. Instead, **arable land is managed to maximise outcomes across economic, environmental and social dimensions**.

Two of the major ways to increase productivity of land sustainably are by **increasing yields above baseline**, and **applying double-cropping**.

- Yield increases can be achieved through improved fertilizer applications, mechanization, better seeds, precision farming, modern irrigation techniques, application of drones, etc. In short, it is possible that increased production of feedstock does not imply the application of more inputs, thus the burden on the environment is not increased, even reduced.
- Double or multi-cropping is a technique where an extra crop is cultivated in a given year on the same plot. Typically, a short rotation cycle energy crop (e.g. sorghum) is produced before or after the regular crop cultivation. Double cropping increasingly allows farmers to increase the harvested area on shrinking agricultural areas[6]. The spread of multi-cropping techniques, such as the establishment of a winter cover crop, can bring additional environmental benefits in terms of the soil erosion and soil emission (GHG) profile of cropping.

As noted, the key to sustainable intensification is more efficient use of inputs and improved management techniques. It is not the fertilizer applied on land that contributes to nitrification, but the fertilizer that is not used by the plants. In these cases leaching of nitrogen occurs which may result in soil and water pollution. By precisely applying fertilizer tailored to the specific need of each plant, leaching is reduced, thus abating soil and water pollution. Precision farming technologies has been around for some time, and now latest technologies, application of drones and processing of big data will further stimulate resource efficiency, and mitigate emissions. Data-enabled agriculture allows for better decision-making through more specific knowledge (e.g How fast the wind was blowing when I sprayed?). In our interpretation **precision farming techniques complemented by drones and "big data" processing at landscape level comprises sustainable intensification**, and, perhaps, it may bring us to the next stage in crop production development.

Elements of sustainable intensification

What are the key elements of sustainable intensification? There are many options, ranging from the adoption of new technology, to improving the efficiency of current crop production. Based on Smith (2013) the following are to be considered:

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[4] Smith, P. (2013); Delivering food security without increasing pressure on land, Global Food Security, Volume 2, Issue 1, Pages 18-23

[5] http://www.siplatform.org.uk/

[6] Langeveld, J. W.A., et al. (2014), Analyzing the effect of biofuel expansion on land use in major producing countries: evidence of increased multiple cropping. Biofuels, Bioprod. Bioref., 8: 49–58

- Agronomic mechanisms for increasing crop productivity include; (i) better matching of nutrient supply to crop need (e.g. improved fertilizer management and precision farming), (ii) better recycling of nutrients, (iii) improved soil management (to reduce erosion, maintain fertility and improve nutrient status) and (iv) better matching of crops with the bioclimatic regions where they thrive.
- The possibility of advancing the limits of crop production. Conventional breeding (or genome sequencing) techniques will allow a range of crops to be developed more quickly than has been possible in the past. This will occur without the reliance on increased water and fertilizer intensity that characterised the Green Revolution.

Technologies are readily available and rapidly evolving. The use of GPS and GIS technologies and modern farming machinery enables site specific application of the right amount of input materials (e.g. N fertiliser) at the right time. The application of drones (Unmanned Aerial Vehicles or Remotely Piloted Aircraft Systems) is a promising innovation in farming, with multiple benefits. Data from drones assessing the level of moisture in the topsoil, the chlorophyll content of the crop and its biomass, may be used for adjusting the spread of N fertiliser to the optimal level required for every part of the farm. In this way it is not just yields that are raised, but N leaching is reduced and nitrification and/or eutrophication are mitigated.

Likewise, sensors mapping the field can detect the greenness of the plants, and as plants with too little nitrogen tend to turn pale it can guide the amounts of nitrogen to be applied. Similar logic applies to the use of pesticides. Infections can be quickly prevented from spreading as drones, fitted with multi and hyperspectral cameras and heat detectors, can spot anomalies or temperature rises typical in many diseased (or nutritionally deficient) crops and timely action can be taken.

Spraying fields by drones can also be more efficient as flying at lower altitude less pesticide is carried off by the wind, furthermore, rotors shake the leaves and their underside can be covered too. In short, **clever technology may increase resource efficiency in cropping**.

These elements may be complemented by ecological intensification principles and measures, where the focus is more on replacing some inputs with ecological services, such as pollination.

Benefits

There are various benefits from sustainable intensification of arable farming, ranging from climate change mitigation (i.e. additional biomass produced to be used for bioenergy purposes leading to GHG saving or improved soil carbon emissions as a result of reduced GHG emissions from nitrification); environmental benefits (i.e. increased efficiency in fertiliser and pesticides use possibly contributing to reduced nitrification and human health impacts or the application of winter crop cover contributing to lower soil erosion and improved biodiversity); agricultural sector (i.e. transferring of know-how, innovation, big data analytics, or investments in latest technologies); or social (i.e. creation of novel social infrastructure that builds trust among individuals and agencies[7]).

Scope in Europe

Despite the fact that sustainable intensification holds great promise, the concept currently has had little coverage in the policy domain. Discussions in general about the nexus of farming and bioenergy insufficiently include actual ways how best to realise the potential. Nevertheless, there is large potential in Europe to produce additional bioenergy feedstocks as well as food, feed and fiber in a sustainable way.

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[7] Pretty et al. 2011, Sustainable intensification in African agriculture, International Journal of Agricultural Sustainability, 9:1, 5-24

We are, however, not promoting the conversion of low-input, extensively managed, species-rich grassland to highly intensified, uniform, species-poor monocultures. Considering only arable land that is cultivated by “intensive farming technologies”, there is a case for sustainable intensification. Note this does not apply to all agricultural lands in Europe. Various forms of agricultural land use, such as small scale organic arable farming or extensive grasslands, will not be the subject of this approach. Also, agricultural land use where ecosystem services or non-commodity outputs are significant should not be subject to this approach. In general it is already intensively cultivated arable fields with unsustainable practices that may benefit the most from sustainable intensification. In addition to poorly performing conventional arable fields, the focus of sustainable intensification is cropping systems where high input use is associated with unnecessarily high emissions and relatively low yields.

Sustainable intensification is a technological means also to **closing the yield gap**. The difference between actual yields in a region and agro-climatically achievable yields in the same region is termed the ‘yield gap’. Science has pointed out that there is a large yield gap in many European countries[8]. Mueller et al. (2013)[9] found that large production increases are possible globally from closing yield gaps to attainable yields, and the changes to management practices that are needed vary considerably by region and current intensity.

The authors also find that there are large opportunities to reduce the environmental impact of agriculture by eliminating nutrient overuse, while still allowing an approximately 30% increase in production of major cereals (maize, wheat and rice). Assessing agricultural productivity and climate change implications of closing the yield gap Valin et al. (2013)[10] find that sustainable land intensification would increase GHG savings by one-third when compared with a fertilizer intensive pathway.

The way forward: policies supporting sustainable intensification

Sustainable intensification allows for increasing the availability of biomass without increasing the burden on the environment, which is key to producing more bioenergy (and food, feed and fibre). Science indicates there is a large scope for increasing biomass availability in Europe in a sustainable way, hence fostering bioenergy production. Technologies are available, their uptake will need to be supported, however it will not happen autonomously. In addition for a need to reduce environmental impacts, evidence shows that the yield gap persists in many countries[11], and sustainable intensification could be the comforting answer. Why has it not happened yet on a large scale? Perhaps, market incentives were missing. With bioenergy production now increasingly relevant, the necessary market push may arise. Bioenergy may be the catalyst for moving towards sustainable intensification.

It is high time discussions on **climate, agriculture, environment and energy policies** feature the various promises of sustainable intensification. Note that the knowledge economy may also be strengthened, as sustainable intensification essentially links to application of “big data”. Decision-makers will need to acknowledge the potential benefits and enabling and/or supporting policies will need to be designed and implemented.

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[8] Wicke, B., Faaij, A. et al (2015): iLUC Prevention Project. Copernicus Institute of Sustainable Development at Utrecht University

[9] Mueller, N.D., et al. (2013): Closing yield gaps through nutrient and water management. Nature 490, 254–257

[10] Valin, H. et al 2013: Agricultural productivity and greenhouse gas emissions: trade-offs or synergies between mitigation and food security? Environmental Research Letters 8

[11] Wicke, B., Faaij, A. et al (2015): iLUC Prevention Project. Copernicus Institute of Sustainable Development at Utrecht University