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CROPDIVERSITY

'...we should not only seek diversity within cropping systems, but within agriculture as a whole — diversity in farmers, in incentives and in perspectives. True resilience, after all, comes from diversity in every form.'

By Lotte van Dueren den Hollander
2024 Nuffield scholar
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SETTING THE SCENE

With my Nuffield research I focussed on the potential of crop diversity for Dutch agriculture.

This topic has my interest because I feel there are more and smarter ways to use crop diversity for sustainable or regenerative agricultural going into the future.

My name is Lotte van Dueren den Hollander. I was born and raised on an arable farm in Oud-Beijerland, the Netherlands. You could say that my interest in, especially arable, farming was spoon-fed. However, I became consciously interested around the age of 16, when I started looking more actively to ways I could work and participate on the farm.

This led me to studying Plant Sciences in Wageningen and after starting my first 'real' job at BO Akkerbouw (trade association for arable farming), with parttime working for the farm at home. To me, it's very important to keep a connection with actual farming in practise, because I want to know what I'm talking about.

Crop diversity has been of interest to me for a longer time. It started with an interest in cover crops and had expanded to crop diversity in the broadest definition. What lead me to focus my Nuffield research on this topic is an experiment at the farm at home.

There we are trying to implement companion plants with potatoes. First results were positive. 'If this works well, what else is there to explore?' was my thought.

This report is meant as a summary of what I learned during my Nuffield studies, in terms of my study topic, but also personally. The report is meant for anyone who wants to read about my research on crop diversity. It should be noted that it's experience-based research, and not scientific research.
I hope to spark broader interest in the topic of crop diversity.

This journey wouldn't have been possible without a number of organizations and people. First of all, I'd like to thank my sponsors Rabobank, LTO Noord, Royal Cosun and BO Akkerbouw. Next, I'd like to thank people close to me, for supporting me and making it possible for me to successfully complete my scholarship. Be it by providing me with the support to leave home for weeks at a time, or for listening to me whilst Nuffield was challenging me to keep going. Thank you!

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THE QUESTION THAT GREW

As mentioned, my interest in crop diversity has been there for some time now. It was the experiment at our farm with the companion plants in potatoes which made me think 'What else is there to try?'. The idea behind the companion plants in the potatoes is, depending on which plants you choose, to fix nitrogen from the air and to attract more beneficial insects and therefore being able to reduce the amount of artificial nitrogen and crop protection applied. It also forced us to stop using any herbicides in these potatoes, seeing that the companion plants otherwise would not survive. During the experiment we came to wonder if there are more benefits: what about the effect on soil structure, distraction or confusion of plague insects, stress reduction under harsh conditions, etc.

I see a big interest from arable farmers to try or switch to new, even more sustainable or regenerative practices. At the same time the number of crop protection products keeps decreasing.
In arable farming in the Netherlands, we try to continue taking steps into Integrated Crop Management (ICM) (Figure 1). ICM is a framework which describes which steps should be taken into account to prevent diseases or plagues in the first place, and which steps should be taken into account when combating diseases and pests.

Figure 1: The Integrated Crop Management (ICM) framework with the five pillars: 1) crop diversity in space and time, 2) variety and cultivation method, 3) soil, water and fertilization, 4) targeted control and 5) monitoring and evaluation. Source: Wageningen University and Research

As seen in the figure, crop diversity in space and time is part of the ICM-framework. I feel like more aspects in this regard can be explored, to use the full potential of this pillar in the ICM-framework.

01 THE QUESTION THAT GREW

Therefore, I came up with the following research question and sub-questions:

What is the potential of various forms of intercropping/crop diversity for agriculture in the Netherlands?

1. What is the potential of intercropping crops within a single cropping cycle on a single field (such as intercropping wheat and field beans)?
2. What is the potential of intercropping different varieties of a single crop within a single cropping cycle on a single field?
3. What is the potential of intercropping crops with non-productive plants (e.g. companion plants) within a single cropping cycle on a single field?

To investigate this, I travelled inside and outside of the Netherlands to speak with various farmers, researchers and other stakeholders. Like mentioned before, this is an experience-based research, not scientifically based.

I deliberately did not focus on systems such as agroforestry or strip cropping. These systems often require major changes in farm layout or management. Instead, I was more interested in forms of crop diversity that can be applied within existing cropping systems — approaches that don't demand a complete redesign of the farm, yet can still have a significant impact.

02

FINDINGS FROM THE FIELD

During my Nuffield travels I visited people in the following countries: Brazil, Ireland, Borneo (Malaysia), Germany, Taiwan, Japan, Poland, Italy, United Stated of America, Canada, England, Wales and the Netherlands.

Looking back on all the visits, there is a few common themes or reasons why crop diversity is useful. I will describe them below and provide the examples I have come across.

Crop diversity as a facilitation strategy

With crop diversity as a facilitation strategy, I mean a system where one crop is introduced not primarily for yield, but to physically or ecologically support another crop. Examples of this I found:

- Borneo: A vanilla farm where the owner worked with permaculture system. He mentioned working with 'sacrificial plants'. Plants that are grown literally to support other plants. Like vanilla growing on a tree trunk (Figure 2).
- USA and the Netherlands: Mixing corn varieties for physical support. One variety is highly digestible for cows but prone to lodging, while the second is sturdier. By alternating rows of both, the risk of lodging is decreased while still having good enough digestible feed.
- Germany: Drilling leaf rye as a cover crop and direct drilling soy beans or other crops in this crop (Figure 2). Then wait until the crop are tough enough to take a hit and roll the whole field with a shrink roller. The leaf rye stays flat on the soil and acts like a mulch layer, where the soybeans shoot up straight again and continue growing. This, among other benefits, holds more moisture and suppresses weed growth.

Figure 2: Left: Vanilla having a tree trunk as support to grow, the tree being the sacrificial plant (Borneo). Right: Leaf rye cover crop with main crop having being drilled directly in the leaf rye (Germany).

02 FINDINGS FROM THE FIELD

Crop diversity for input reduction

With crop diversity for input reduction, I mean a system where a second crop/plant species is introduced to reduce input like fertilizer, crop protection or labour. Examples of this I found:

- Brazil: Came across a farm where they, because of a lack of labour, prune half of the coffee plants thoroughly, causing them to not produce for one year. The next year the plant gives about double the yield. They plant soybean in between the rows, one row yes, the other row no, to provide a little money, fix nitrogen and cover the soil (Figure 3). That way, they compensate a little of the financial gap because of the pruning.
- Canada: A farmer growing non-GMO soybean using his own seed for 10 years now. The seed is drilled naked (so no disinfecting and priming) and the crop does really well. What is interesting is that soybean is an open pollinated crop. So, since he has been using his own seed for 10 years, it has probably become a landrace adapted to his field's conditions.
- Ireland: Using legumes as companion plants in grains (Figure 3). They help with quicker soil coverage and fixing nitrogen. So, it reduces the amount of herbicides and nitrogen needed.
- Ireland: Using mixtures of varieties in wheat. Trying to make use of the strong components of every variety, whilst supporting each other's weaker characteristics. This particular farmer tried mixing up to ten varieties, which he stated as 'overdoing it a little', however he was very positive about working with this method.
- Poland: The same farmers who adds fenugreek as companion plant for insect repelling, also adds legumes to fix nitrogen. During winter, the legume freezes and after the nitrogen is released for the oilseed rape to use.

Figure 3: Left: Coffee plants with soybean in between (Brazil). Right: Wheat with legumes as companion plants (Ireland).

02 FINDINGS FROM THE FIELD

- England: Only briefly mentioned by a farmer I visited, however a good example why crop diversity for input reduction is a good thing, is that a large part of sugar beet production has been concentrated in one area in the UK. This has led to relatively big issues with aphids and virus infections.
- England: A farmer mixed two potato varieties and his buyer was happy with taking the yield mixed. This regards potatoes for fries.
- USA: Relay cropping soybean and wheat keeps the soil covered for a longer part of the year (Figure 4). That way water is retained better, nutrients are more efficiently utilized due to the staggered development of the two crops and the light use efficiency is higher.

Figure 4: Relay cropping wheat and soybean (USA).

- Japan: At Takii Seeds they they don't specifically breed for intercropping; however, they do sell some crops in combination because one benefits the other.
- Netherlands: Adding barley in sugar beet crop to reduce the risk of aphids, needing less insecticides for aphid control.

Crop diversity for landscape resilience

With crop diversity for landschape resilience, I mean a system where a second crop/plant species is introduced to reduce the possible risk of extreme weather conditions and climate change. Examples of this I found:

- Taiwan: Betel nut grows very shallow roots and are grown on hill/mountainsides a lot. Areas are deforested to plant betel nut trees, often together with one or two other crops underneath the trees. In 1999 Taiwanese people experiences the dangers of deforesting and planting the shallow rooting betel nut trees. They suffered an earthquake which caused big landslides, especially in areas with betel nuts. So here the lack of diversity causes an unstable landscape.
- USA: On the steeper slopes of his hillsides, a farmer was planning planting perennials to reduce soil erosion and minimize risky field operations.
- USA: A study was executed which confirmed how systems like relay cropping can improve water infiltration and holding capacity during heavy rainfall, reducing the risk of flooding.

02 FINDINGS FROM THE FIELD

Diverse cropping systems including animals

Studying my topic, I ended up visiting lots of people who are regenerative farmers. In regenerative farming, including animals in the system is an important aspect. Now animals are not a crop, however can be included in a crop rotation, which is the reason I mention them here. I came across several variations of this idea.

Figure 5: Relay cropping wheat and soybean (USA).

- In the USA I came across a system where cover crops are combined with corn in wider strips. These cover crops can be grazed by cattle, either through strip grazing, virtual fencing, or systems such as the Stock Cropper (Figure 5). This would be during summer.
- Another way, which I came across in the USA and England, is grazing cattle on a cover crop during winter using virtual fencing. Either on a fully mixed cover crop or on different patches of cover crops, making sure the animals have some of each type the whole time.

Farmers shared their experience and knowledge on how grazing cover crops stimulates new root growth, which benefits soil health, while also adding value as feed. It was even mentioned that the saliva of the animals can work as a biostimulant for the cover crop.

Markets

Of course, changes in crop diversity may come with additional costs or the need of a buyer who is interested in the new crop. Travelling through the Corn Belt in the USA it was not a surprise that crop diversity was very limited. When asking farmers why, the answer was often the same: a lack of markets. For example, relay cropping works well for soybeans, but finding a buyer and a good price for the wheat is a challenge.

At the University of Minnesota, I met a professor, who works for the Forever Green Initiative. This program focuses on developing new crops and markets for the upper Corn Belt. What makes it unique is the active collaboration with the private sector and attempts to engage government as well. They realized that new crops do not only require agronomic research, but also a new supply chain, policy support and financing structures. This approach was inspired by Dutch frameworks, something that is not common in the USA and might be part of the explanation of the lack of markets for other crops.

02 FINDINGS FROM THE FIELD

In England a visit to Wildfarmed was really interesting to learn more about how to market crop diversity (Figure 6). Wildfarmed requires farmers to grow their grains according to a specific set of principles, making it regenerative wheat. Two of those principles is having to grow grains with companion plants or pulses and mixing varieties. What Wildfarmed has done, is providing the supply chain and market from grower to end-user or retailer. They have also managed to find water companies willing to pay farmers who are in 'high risk emission to water' areas to become a Wildfarmed grower. To me, it is a great example which shows it can be done. Still however, it remains difficult to find ways to provide farmers with the extra money they should be receiving for the added value they are creating. For a niche product/crop it remains easier than for a large volume or a crop/product where it is difficult to provide the supply chain all the way to the final consumer.

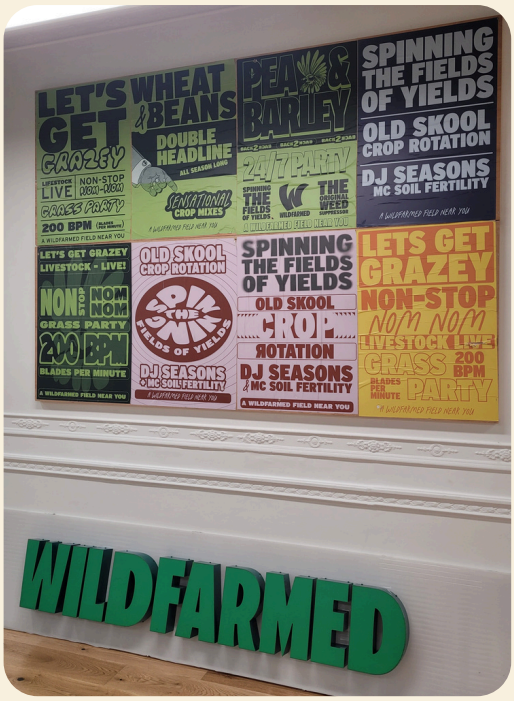


Figure 6: At the office of Wildfarmed in London (UK).

Risks and barriers for crop diversity

Next to the lack of market opportunities, I came across several other risks and barriers to applying crop diversity. One is simply getting used to a new way of working, which is never easy. For instance, adding companion plants means herbicides can no longer be applied, as they would also terminate the companion species. This calls for new weed management strategies. In addition, some people mentioned that diverse systems are often perceived as "messy," which can be a psychological or social barrier for adoption.
Another challenge mentioned in the U.S.A. was crop insurance, which is usually unavailable for less common crops or mixed systems.

Interestingly, the need for new machinery is often seen as a complication, but many farmers I met proved that it does not have to be. Instead of investing in modern, specialized equipment, they often used older, simpler machines that they modified themselves. This creativity allowed them to make small practical changes with a big impact, without having to redesign their entire system or buy expensive machinery.

Harvesting can also be a challenge in mixed systems, for example when combining grains and legumes. Either you need a buyer willing to take the mixed product, or you must separate seeds post-harvest — both of which can increase costs and com-

plexity. However, maybe we can think of clever alternatives, such as mixing crops with smaller-seeded plants that pass through the combine and with that reseed the field.

A more pressing issue, which requires further research, is the potential risk of breaking disease resistance when mixing crop varieties. In Ireland, a researcher at Teagasc shared a hypothesis that mixing susceptible and resistant varieties could increase disease pressure and potentially trigger resistance breakthrough. At Takii Seeds in Japan, it was mentioned that mixing can work when using strong, stable resistance genes that are less prone to breakthrough. This is crucial to consider, as resistance genes are limited and need to be safeguarded carefully.

03

KEY TAKEAWAYS AND WAY FORWARD

What I found during my Nuffield travels is that there is a world of potential to be discovered when it comes to crop diversity – or intercropping - in its broadest sense. Most current practices focus mainly on diversity in time and space at field scale, such as crop rotation or considering neighbouring fields. Yet, during my journey I found many inspiring examples that go beyond this — integrating crops, varieties and non-productive plants within a single cropping cycle.

What surprised me most, however, was the variety of motivations why to apply crop diversity. In some cases, diversity was used as a facilitation strategy, where one crop supports the other. Others used it for input reduction, such as reducing the need for fertilisers or pesticides. I also encountered crop diversity applied for landscape resilience, improving water infiltration or preventing erosion, and finally, systems where livestock was reintroduced as an extra layer of diversity.
Concerning my three sub-questions, I found that:

01 Intercropping different crops

The fact that I came across relatively little examples of intercropping different other than relay cropping soybean and wheat, in my opinion shows this is one of the trickier ones to apply without requiring larger adjustments. There might be potential, but it needs more investigating.

02 Intercropping different varieties

Mixing different varieties of a single crop seems to be one of the most accessible forms of intercropping, surely for mowing crops. However in the Netherlands our cash crops are digging crops, which are more tricky when mixing varieties but this does not mean it can't be done, with the potato grower in the UK as example.
It is important to note that more research is needed to understand the potential risks of resistance breakdown.

03 Intercropping with non-productive plants

Intercropping with non-productive or companion plants — for instance, species that cover the soil, fix nitrogen, or attract beneficial insects — proved to have environmental and agronomic benefits whilst being relatively simple to apply.

03 KEY TAKEAWAYS AND WAY FORWARD

Main conclusions and recommendations

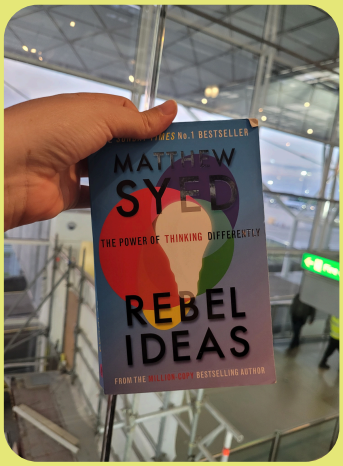
The potential of crop diversity for Dutch agriculture is significant — but its realization depends on how creatively and collaboratively we approach it. Throughout my travels and conversations, I've seen that diversity in cropping systems can provide different ecosystem services: from improving soil health and water retention to enhancing resilience against pests, diseases, and climate extremes. These benefits extend beyond the farm gate. Water companies, insurance firms and other stakeholders stand to gain from a more diverse and resilient agricultural landscape. The challenge ahead lies in identifying and engaging these stakeholders, to jointly invest in the ecosystem services that crop diversity, and farming, provides. If farmers can be fairly rewarded for their effort for further diversifying cropping systems, it lowers the threshold do pick-up these kind of practices.

While some forms of crop diversity are already within reach — such as mixing varieties or undersowing — others still require further exploration and shared experimentation. Developing a coordinated research agenda would help organizations identify where knowledge gaps exist, what practical barriers remain, and how to address them together.
As my end-product for Nuffield I will organise a meeting on crop diversity with a group of stakeholders whom are involved in crop diversity or for whom crop diversity may provide benefits. The idea is that this meeting will be a starting point to set out and go discover more about crop diversity as a collective, identifying knowledge gaps, see where the potential lies and go from there. This meeting will be organised together with BO Akkerbouw.

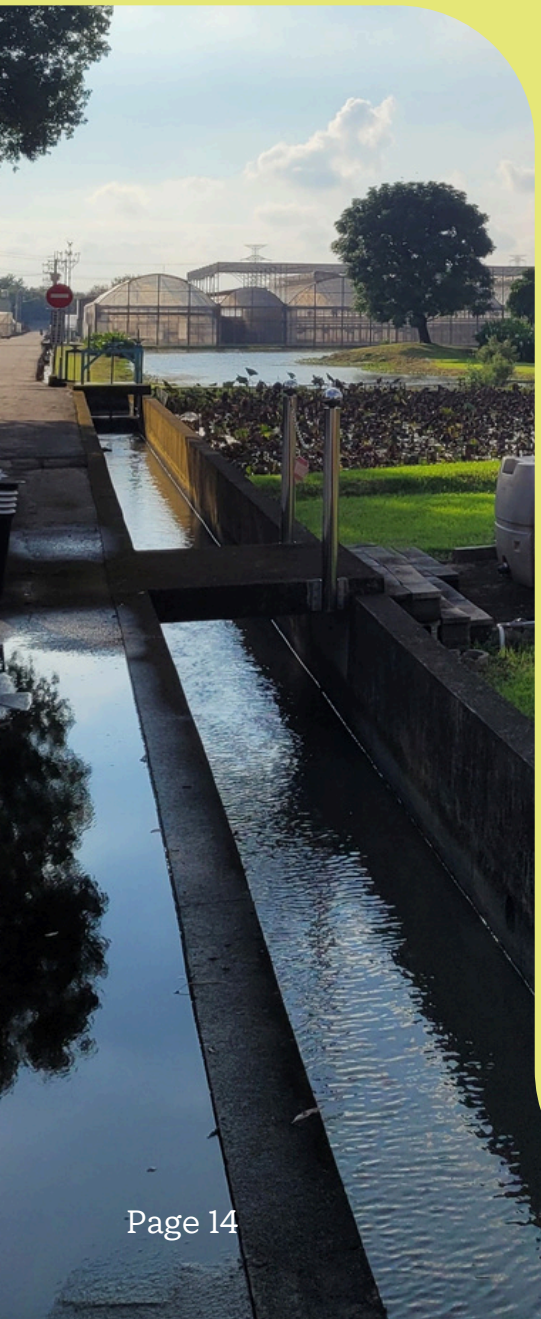
In short, the potential is there. By thinking more creatively about what crop diversity can mean — not only in terms of species, but also in partnerships, incentives, and applications — we can turn this potential into practical, resilient, and regenerative farming systems for the Netherlands.

04

PERSONAL REFLECTION



Tip for reading: Rebel Ideas by Matthew Syed. A book on the importance of diversity for resereach and innovation.



Enabling diversity

During the last six months of my Nuffield journey, I have been reading about what is needed to stimulate innovation and address complex challenges (Figure 6). One key insight is the importance diversity among people. Research shows that diverse groups, bringing together different perspectives and experiences, are more effective at solving problems than individuals or uniform groups with similar frames of reference.

This idea made me wonder: if this goes for people, wouldn't the same principle apply to plant systems as well?

Looking at the Netherlands, we face a range of complex challenges — from climate change and water management to feeding a growing population and biodiversity. Farming can play an important role in addressing these issues. So, what if we combined diverse groups of people and diverse groups of plants to work toward these solutions together?

Therefore, I learned that we should not only seek diversity within cropping systems, but within agriculture as a whole — diversity in farmers, in incentives and in perspectives. True resilience, after all, comes from diversity in every form.

03

PERSONAL REFLECTION

Last personal notes

During the time I did my Nuffield scholarship, I feel like I have been challenged personally in different ways. Looking back, I learned a lot about myself and think I have grown as a person. I have been saying that Nuffield has made the world smaller and bigger at the same time.

I feel like my respect for farmers has grown even more. I did a whole Nuffield scholarship on just one specific topic. Only imagine how many other topics there are in farming, of which a farmer needs to know about at least a little.

It has been amazing to explore the world and having met all these people along the way. Everyone has been amazingly generous with their time, knowledge, kindness and homes.

My motto 'Nooit geschoten is altijd mis', which translated to the saying 'If you never try, you will never know.', is what got me on a flight to Brazil for our CSC. It was amazing to meet our cohort of Nuffield scholars there. A group of farmers who are eager to learn, open to share and willing to make farming a little more amazing. Hopefully this motto will get me to a lot more places and situations to discover.