Climate Change and Agriculture: an Integrated Dutch Perspective

Changement climatique et agriculture : une perspective néerlandaise intégrée

Klimawandel und Landwirtschaft: eine ganzheitliche Perspektive aus den Niederlanden

Roel Jongeneel and Ana Gonzalez-Martinez

Key challenges for policymaking

High animal densities, high yields and high nutrient input levels have characterised Dutch agriculture for a long time. Since the 1980s, this has led to relatively high Nitrogen (N) and Phosphorus (P) surpluses per hectare, associated with high losses of N and significant soil P accumulation (De Vries *et al*., 2021). At the moment the Dutch policy agenda is dominated by one key issue: how to quickly and convincingly reduce Ammonia (NH_3) emissions to de-lock the economy. EU and Dutch courts have rejected the old Dutch N-policy and any granting of building permits has been made conditional on first achieving NH_3 emission reductions, with agriculture being a central player in this.

> "L'élevage et les sols agricoles disposent encore d'un potentiel considérable pour réduire les émissions de gaz à effet de serre d'ici 2050."

The climate challenge, which is the primary focus of this article, is not less serious, even so it is less characterised by today's political urgency. The Netherlands has committed itself to the Paris Agreement on climate. Moreover, the EU, supported by the Dutch government, has developed an ambitious climate policy aimed at achieving climate neutrality by 2050. As a follow-up to their climate commitment, the Dutch government has developed a national Climate Agreement (Klimaatakkoord). This agreement consists of a package of measures with the aim of reducing CO_2 emissions by 49 per cent by 2030 relative to 1990, an objective which has been fixed in the Dutch Climate Law. Following the recent increase in EU ambitions, the Netherlands is now considering increasing its reduction percentage from 49 per cent to 55 per cent. Dutch agriculture (including horticulture) has reduced its CO_2 emissions by about 17 per cent relative to 1990 (Klimaatakkoord, 2019, p. 17). This implies that in the coming 10 years, a 38 percentage point reduction still has to be realised, which will be a great challenge.

The Netherlands is known for its polder-model or stakeholder consultation-approach, which has been ingrained in Dutch DNA through its long fight against flooding. The achievement of the national Climate Agreement is again an example of such a collective action as it came about through the cooperation of

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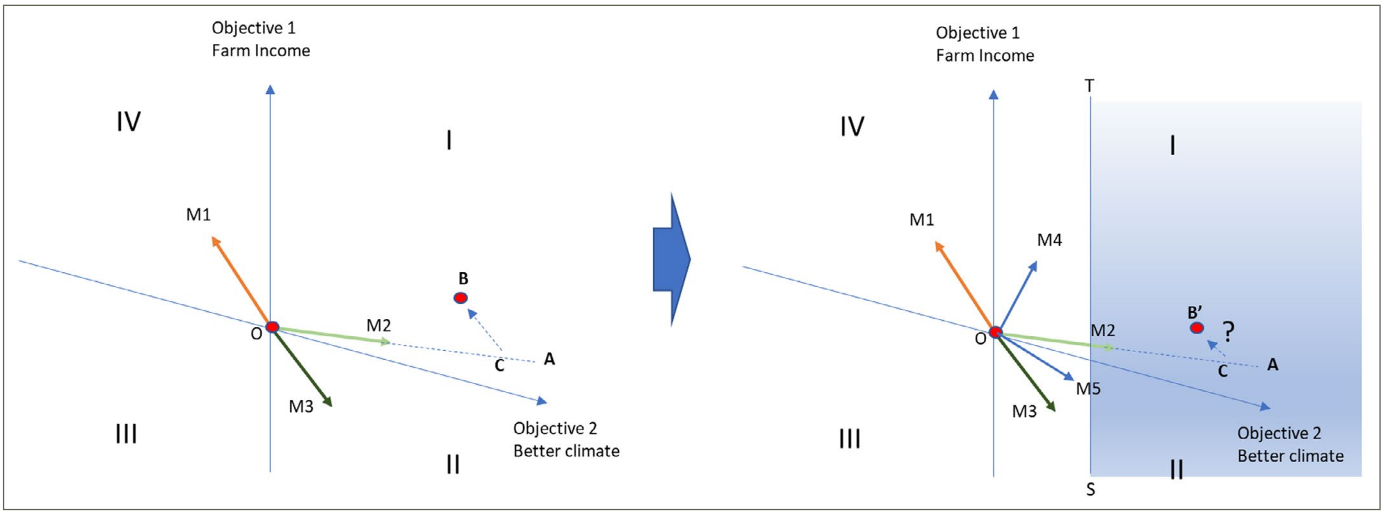
Figure 1: A vector representation of the extended Tinbergen approach



Note: The graph distinguishes two policy objectives (income, climate) and different individual policy measures (arrows M1–M5), which have a different performance with respect to each of the objectives. Only their combined use can help the sector to move from O (its current situation) to B (left panel), assuming the available budget allows this. Due to climate and other sustainability objectives the policy space is restricted (see shaded area), which increases the complexity of policy optimisation (right panel). The change in policy direction (more eastward) goes together with newly developed policy measures (including innovative technologies) such as M4 (e.g. eco-schemes) and M5 (e.g. manure separation). Past policies often ended up in quadrant IV (improving farm income but at the expense of the environment). In the new situation, with more emphasis on the climate objective, with the existing policy measures and budget achieving a certain farm income level may no longer be feasible.

more than 100 parties. Stakeholders from various subsectors (e.g. dairy, intensive livestock) and backgrounds (e.g. processors, retailers, NGOs) have been involved and contributed to a package of measures that should help to realise the predefined national ambitions. The main focus of the current agreement is on the medium term (until 2030). In order to provide additional insights into the actions needed for the longer term (until 2050), a special study exploring different scenarios has been issued. Its set-up and results are discussed below.

Policy trade-offs and ways to overcome these

Given the multiple challenges mentioned above, and the need to adhere to the legal commitments to several sustainability and climate objectives, an integrated policy approach is needed. Not only are there interrelations between the policy objectives but also the measures to be taken are likely to simultaneously affect different objectives. This context imposes the need for policy optimisation, for which the fundamentals have been developed by the Dutch economist Jan Tinbergen, who was awarded the Nobel Prize for his contribution to this subject. Tinbergen emphasised the various trade-offs that have to be considered in policy making: there are always multiple objectives which may run in parallel, but more often compete or even conflict with each other. But he also has a message of 'reconciliation': smart policy approaches could contribute to overcoming trade-offs and to the simultaneous realisation of objectives. His famous policy rule is that, *'one needs at least as many policy instruments as there are objectives'*. A vector representation of his theory is illustrated in Figure 1, left panel: If agriculture, for example has to satisfy both a farm-income and a climate objective, and aims to improve from its current situation O to 'bliss point' B, with only one policy measure (say M2) even though it is well selected, i.e. is better than M1 and M3, it will not achieve the goal as B cannot be reached, but only points on line OA. However, by combining M2 and M1 with certain intensities (M2: OC and M1: CB) B can potentially be achieved. We have added more measures to the classical Tinbergen approach, i.e. M4 and M5 (right panel), of which some are innovative; and at the same time, we limited the policy space (shaded area), constraining any climate performance below ST. In contrast, traditional agricultural policies would have ended up in quadrant IV (better income, but worse environment). Given the Climate Agreement only parts of quadrants I and II are allowed to ensure that a minimum climate objective can be achieved.

> "Sowohl bei der Tierhaltung als auch bei den landwirtschaftlichen Böden gibt es noch ein erhebliches Potenzial, die Treibhausgasemissionen bis zum Jahr 2050 zu reduzieren."

The Tinbergen framework not only emphasises the need for an integrated approach in the policy domain but this has to be mirrored in the analytical approach by bringing researchers from different disciplines together in collaborative working sessions employing a set of modelling tools. The backbone of this approach was the combined use of a core economic model (AGMEMOD) and a core environmental model (INITIATOR); other complementary tools, including new innovative technologies were also used to assess

Box 1: An integrated environmental-economic approach

An illustration of how this integrated framework has been applied in the policy-making realm is presented in Gonzalez-Martinez *et al.* (2021). At a very early stage, the interaction among the different stakeholders participating in the mentioned debate revealed the lack of a common understanding of the trade-offs associated with the implementation of a given set of mitigation measures. In order to facilitate the debate on scenario-development, an interactive tool was developed, which could provide a quick first insight into the policy space. The basis of this was a linear programming tool, bringing together all agricultural activities (e.g. crop, dairy beef, pigs, poultry) and the different legislative restrictions (e.g. Nitrate ceiling, Phosphate ceiling) and emission equations (e.g. climate) as constraints. This tool helped to identify how different pieces of legislation, and proposals for change were interacting and did overlap each other. It also showed which restrictions from policy were the most binding and where 'slacks' were still existing, which would allow Pareto improvements to be made (viz. make some stakeholders better off, without making any others worse off).

The level of detail at which modelling outcomes needed to be provided indicated the need for an integrated use of models which captured the key aspects of the 'agriculture-biosphere' system. The core of this modelling approach relies on the AGMEMOD (AGricultural MEmber states MODelling) economic partial equilibrium model and the environmental-ecological model INITIATOR (Integrated NITrogen Impact Assessment Tool On a Regional scale). See: https://agmemod.eu/; and https://edepot.wur.nl/222946). In this specific case, AGMEMOD captures the demand and supply sides of the agricultural market in the Netherlands, while INITIATOR calculates the environmental consequences (nutrient flows and emissions) associated with a certain production volume which is previously determined by AGMEMOD. As a complementary tool an input/output model has been linked to the AGMEMOD model in order to capture supply chain impacts. Moreover, the models are enriched with new emissions reducing technologies and management practices (see Table 1 for a brief overview of the measures which comprise each mitigation package).

Table 1: Selected mitigation packages for different livestock categories

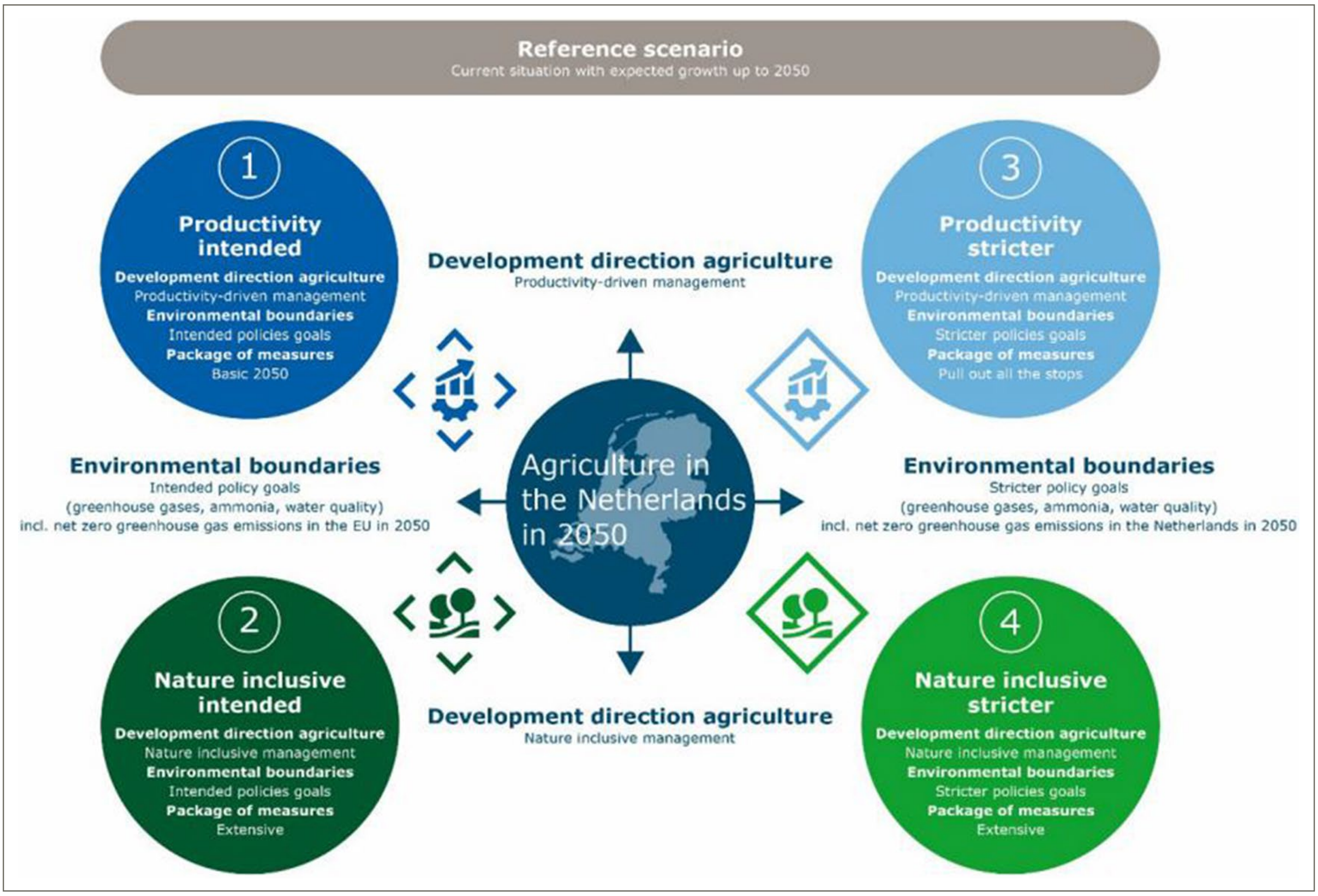
Category		Mitigation package		
		'Basic 2050'	'Pull out all the stops'	''Extensive'
Stables	Dairy cattle	– Primary separation and frequent removal of faeces and urine, with CH_4 and NH_3 removal in manure storage. – Capture and remove part of the CH_4 in exhaled breath.	– Primary separation of faeces and urine. – Closed, airtight stables with CH_4 and NH_3 removal.	– Primary separation and frequent removal of faeces and urine, with CH_4 and NH_3 removal in manure storage. – Capture and remove part of the CH_4 in exhaled breath.
	Pigs	– Primary separation and frequent removal of faeces and urine, with CH_4 and NH_3 removal in manure storage.	– Primary separation of faeces and urine. – Closed, airtight stables with CH_4 and NH_3 removal.	Primary separation and frequent removal of faeces and urine, with CH_4 and NH_3 removal in manure storage.
	Poultry	– Manure drying and frequent removal (common techniques)	– Manure drying and frequent removal (highly effective techniques)	Manure drying and frequent removal (common techniques)
Access to pasture or outdoor area	Dairy cattle	Grazing 80% of national herd, 720 hours per year	No grazing	Grazing 100% of national herd, 3600 hours per year
	Pigs	No access to outdoor area	No access to outdoor area	All animals have access to an unpaved outdoor area
	Poultry	Broilers: no access to outdoor area. Laying hens: access to an outdoor area on part of the farms	No access to outdoor area	All animals have access to an unpaved outdoor area
Animals and productivity	Dairy cattle	Milk production 11315 kg head^{-1} yr^{-1} Genetic selection on lower enteric methane emissions	Milk production 12635 kg head^{-1} yr^{-1}	Milk production 9335 kg head^{-1} yr^{-1} Genetic selection on lower enteric methane emissions
	Pigs	36 piglets sow^{-1} yr^{-1} Feed conversion fattening pigs 7% lower	38 piglets sow^{-1} yr^{-1} Feed conversion fattening pigs 20% lower	30 piglets sow^{-1} yr^{-1} Feed conversion fattening pigs same as current
	Poultry	Laying period 100 weeks Weight gain broilers: 49 g head^{-1} day^{-1} (35% of broilers) or 59 g head^{-1} day^{-1} (65% of broilers)	Laying period 120 weeks Weight gain broilers: 59 g head^{-1} day^{-1}	Laying period 90 weeks Weight gain broilers: 43 g head^{-1} day^{-1}
Feed rations	Dairy cattle	Grass 60%, maize 15%, by-products/concentrates 25% Feed additives for reduction of enteric methane	Grass 50%, maize 20%, by-products/concentrates 30%	Grass 70%, maize 10%, by-products/concentrates 20% Natural feed additives for reduction of enteric methane
	Pigs	Moderate reduction of protein in feed ration Benzoic acid added in feed ration	Strong reduction of protein in feed ration Benzoic acid added in feed ration	Reduction of protein in feed ration Benzoic acid added in feed ration
	Poultry	Moderate reduction of protein in feed ration	Strong reduction of protein in feed ration	

Source: Reproduced from Gonzalez-Martinez *et al.* (2021).

specific trade-offs. Although the focus was on climate impacts, together these tools could cover economic aspects as well as the environmental ones with respect to P, N, NH_3, and run-off of effluent to water.

The increasing body of environmental legislation and societal concerns is challenging Dutch agriculture and

Figure 2: Overview of the scenarios



Source: Reproduced from Lesschen *et al.* (2020).

requires it to be transformed but the decision of how to reshape it is not a trivial one. There are multiple trade-offs among the different activities that comprise agriculture. Reducing the herd size of the livestock sector (as was proposed by some stakeholders) may reduce emissions but at the cost of value added in primary agriculture and its supply chains. Reducing emissions by adopting innovative technologies could provide a more attractive pathway to simultaneously achieve two objectives but several technologies are still in a very initial laboratory-phase and not yet ready for implementation. In order to assess the trade-offs, firstly information on new technologies with promising potential has been collected by gathering information from public and private sector research centres, including extensive discussions with technical experts. Subsequently, this information had to be translated into modelling terms, in order to allow the modelling assessment to generate the impact of these technologies; and together with the multiple environmental constraints (including limiting GHG emissions and others) determine what combination of both pathways could solve the 'policy problem' at least cost. As the technologies would have implications for the farming system, a discussion was initiated to consider the climate challenges in combination with different farming-system directions.

Scenarios to explore options

Based on the discussions with the stakeholder group, a set of four scenarios was chosen to cover the realm of policy choices: (1) productivity intended; (2) nature inclusive intended; (3) productivity stricter, and (4) nature inclusive stricter. They vary with respect to the strictness of the environmental objectives (see details in Table 2) and the farming system (productivity-oriented versus nature-inclusive oriented) and the measures taken at farm level (see Table 1).

An overview of the combination of drivers that is assumed in each scenario is presented in Figure 2.

Table 2: Agri-environmental scope for intended and stricter sustainability boundaries

Topic	Emissions 2017	Intended policy goals 2050	Stricter policy goals 2050
Climate (CH_4 and N_2O)	19 Mton CO_2-eq	9 Mton CO_2-eq	Net zero emissions in NL from agriculture and land use
Climate (land use)	6 Mton CO_2-eq	2 Mton CO_2-eq	Net zero emissions in NL from agriculture and land use
Ammonia	110 kton NH_3	85 kton NH_3	50 kton NH_3
Nutrients (N and P) leaching and runoff	45 kton N 3,7 kton P	N: -12% P: -12%	N: -17% P: -17%
Nutrient cycles	n/a	Closing feed-manure cycle within Europe	Closing feed-manure cycle within Europe

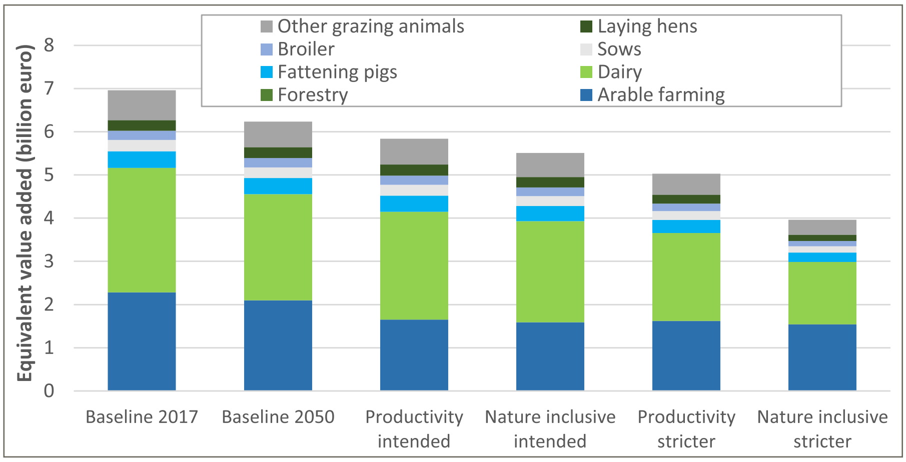
Source: Lesschen *et al.* (2020).

More specifically, the options for the environmental boundaries for agriculture associated with the intended and more strict policy objectives (including climate neutrality) are summarised in Table 2. Alongside the objectives already mentioned, it also includes an objective with respect to making agriculture more circular, but this aspect played a minor role in the assessment.

Summary of main results

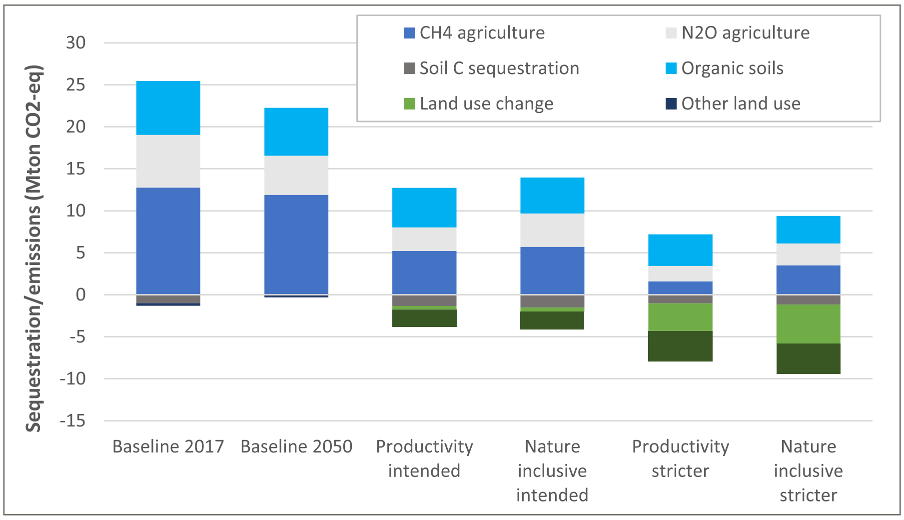
Focusing on the agri-food supply chain, Figure 3 presents the impacts on 'equivalent' value added for each scenario. Since technologies, prices, costs and required investments by 2050 are still uncertain (to the extent that agricultural commodity prices were included in the so-called SSP (Shared Socioeconomic Pathway)-scenario) or lacking (in case of new technologies) the choice was made to at least show the income impact equivalent with the current value added or 'gross margin' (difference between revenues less non-factor inputs). Note that this indicator, while focusing on revenues minus normal operational costs (e.g. feed input) does not include the full costs associated with the management actions and investments farmers need to take as this information was largely lacking (in particular with respect to the technologies that are still in development). Adopting strict environmental goals and pursuing Nature inclusiveness stricter (Scenario 4) could lead to a decline in 'equivalent' value added of agriculture and related sectors of around 35 per cent compared to the current situation (Baseline 2050), i.e. around a 2 billion euros loss for the primary agricultural sector. An important qualifier is that the reported 'equivalent' income statistic does not yet include an estimate of the adjusted government support to facilitate the climate transition, which could contribute to reducing the costs for farmers. However, looking at the available CAP budget and rough calculations of the amount of money needed it is most likely that farmers will have to pay at least part of the bill themselves.

Figure 3: 'Equivalent value added' by agricultural activity



Source: Reproduced from Gonzalez-Martinez *et al.* (2021).

Figure 4: Estimated emissions from Dutch agriculture



Note: Emissions are shown as positive numbers while sequestration is represented by negative numbers.
Source: Reproduced from Gonzalez-Martinez *et al.* (2021).

Figure 4 presents key environmental indicators as computed by INITIATOR, covering the entire greenhouse gas balance for agriculture and land use. The autonomous technological changes and related productivity increases could lead to a decline in the emissions of CH_4 and N_2O from 19.1 to about 16 Mton CO_2-eq. in the baseline case by 2050. In the case of Stricter policy goals herd reductions could not be avoided, whereas in the other scenarios the adoption of emission reducing technology by the agricultural sector could do the job, without there being a need to reduce herds. For the Productivity stricter scenario, a herd size reduction of 18 per cent was necessary, while for the Nature inclusive stricter scenario a herd reduction of 42 per cent was needed to achieve the environmental goals. In all cases it holds that the achievement of climate neutrality by 2050 is only possible by taking specific measures with respect to 160 thousand hectare peat soils (e.g. use of shallower water tables; taking peat land out of agricultural production, etc.) and/or by transforming part of the agricultural land into forest in order to generate the necessary sink for carbon storage.

Ultimately, the outcomes of the pathway that agriculture follows will significantly shape the landscape of the country (Figure 5), increasing or decreasing its value from a biodiversity perspective. These impacts have been assessed in a qualitative way and by visualisations.

These scenarios have assumed a full implementation of the techniques that are included in each mitigation package, as well as their optimal

Figure 5: Landscape under alternative scenarios

Scenario 1 – Productivity intended **Scenario 4 – Nature inclusive stricter**

Source: Reproduced from Lesschen *et al*. (2020). Illustrations by Erik Eshuis.

effectiveness. However, in reality their actual implementation can be expected to occur at a lower diffusion rate. Therefore, the achievement of the intended environmental goals will need to ensure that the deployment of these new technical measures reaches all farmers. In this regard, policy support becomes crucial to the transition, to make possible the adoption of new technology and farming practices.

Future pathways

Several insights follow from the above scenario assessment. Firstly, it turns out that there is still considerable potential from both livestock farming and agricultural soils to reduce greenhouse gas emissions by 2050, even at the current scale of agricultural sectors. This also considers the required reduction of emissions of ammonia to the air and nitrogen and phosphorus to ground and surface water. The degree to which a contraction of the livestock sectors is required depends on the policy goals applied, the development direction of agriculture, the degree of implementation and effectiveness of abatement measures, and the possible increase in the area of forestry to compensate for agricultural emissions.

With a strict interpretation of the climate targets, implying that at national level the emission space for greenhouse gases should not exceed carbon sequestration (in combination with a stricter formulation of policy targets for NH_3 emissions and N and P leaching to water), significant herd reductions ranging from 20 per cent (Productivity stricter) to over 40 per cent (Nature inclusive stricter) are projected. The most limiting objective turned out to be abatement of the greenhouse gases. Targets for NH_3 emissions and N and P leaching to water could be amply met,[2] although for NH_3 and water quality the challenges differ regionally and therefore will require local structural measures. Satisfying climate objectives poses specific challenges for Dutch peat soil farming: the rewetting of peatlands and partly taking these out of production would make an important contribution to greenhouse gas emission reductions (see article on peat soils by Poppe *et al.* in this issue).

> "There is still considerable potential from both livestock farming and agricultural soils to reduce greenhouse gas emissions by 2050."

European policy documents on long-term targets for greenhouse gas emissions assume an emission allowance for agriculture equal to the carbon sequestration through land use change and forests. Under the assumption that there will be differentiation among Member States within Europe when determining the emissions scope for agriculture in 2050 (in combination with continuation of the current policy targets for NH_3 emissions and N and P leaching to water), livestock numbers in the Netherlands do not need to shrink in the Productivity intended scenario and have to do so only to a limited extent (6 per cent) in the Nature inclusive Intended scenario. In the scenarios with the wider, European established emission space for greenhouse gases in 2050, the stricter goals for N and P leaching to water are met, but not quite so for ammonia.

From the simulations it appears that sustainability will compete with farm income, which raises further policy challenges that have not yet been further elaborated on (see also Tinbergen framework). Farm income is not only an objective, but also a side condition in the sense that it should be sufficient for active farms to be able to make the investments and actions needed to make climate transition. The farm income implications are co-determined by policy measures facilitating the development and adoption of new abatement techniques. The recent CAP

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deal, with eco-schemes and its emphasis on budget spending with respect to climate, requires the Dutch government in their National Strategic Plan to align the proposed policy measure implementations with the mitigation strategies and policy options proposed by the stakeholders. Moreover, there could be special policy incentive measures for farmers who want or are 'enforced' to exit the sector. Tinbergen suggests that smart and creative policy choices (combining incentives and regulations) are crucial in aligning economy and ecology and getting them moving in the same climate action direction (Jongeneel *et al.*, 2020). As became clear from some rough calculations much more budget from sources outside the CAP will be needed to facilitate the transition (Baaijen *et al.*, 2021).

It should be emphasised that the scenarios are hypothetical, although well-grounded in expert-based information with respect to future abatement technologies. Moreover, it is assumed that under a specific scenario all farmers will follow this scenario (equipment implementation, farm management measures) and will be fully compliant. Sensitivity analysis has been undertaken relaxing this heroic assumption and shows that with lower rates of measure implementation and/or compliance, herd size reductions would need to be increased to achieve the climate objectives.

Notes

1 This article is based on a study done for the Dutch Climate Table on Agriculture (Lesschen *et al.*, 2020) and financed by the Dutch Ministry of Agriculture and Food.

2 An important factor here is the assumption that by 2050 only stables will be used in which manure and slurry are collected separately as far as possible and quickly removed. This will lead to a considerable reduction in NH_3. If this measure is not included, NH_3 becomes the most binding restriction and more herd shrinkage is needed to achieve the stricter NH_3 targets in 2050.

Further Reading

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Roel Jongeneel and Ana Gonzalez-Martinez, Wageningen University and Research, The Netherlands
Emails: roel.jongeneel@wur.nl; ana.gonzalezmartinez@wur.nl

Summary

Climate Change and Agriculture: an Integrated Dutch Perspective

The Netherlands is facing a set of serious interrelated environmental and economic challenges, some of which are developing to crisis levels. These challenges also impinge significantly on agriculture. With respect to agriculture, Phosphate, Nitrate, water and climate impacts present key environmental challenges. The preservation of biodiversity, landscapes, animal welfare and the use of antibiotics are also elements which could be added to the list. Given the multiple challenges and the need to adhere to the legal commitments of several sustainability and climate objectives, an integrated approach to addressing these challenges is needed. In other words, there is a need for policy optimisation. As a follow-up to their commitment to the Paris Agreement, the Dutch government took action by developing a national Climate Agreement (Klimaatakkoord). In order to provide more insights into the actions needed for the longer run (until 2050), a special study exploring different scenarios was issued, the main outcomes of which are presented in this article with a focus on the climate challenge. This study suggests that there is still considerable potential from both livestock farming and agricultural soils to reduce greenhouse gas emissions by 2050, even at the current scale of the agricultural sector.

Changement climatique et agriculture : une perspective néerlandaise intégrée

Les Pays-Bas sont confrontés à un ensemble de défis environnementaux et économiques interdépendants sérieux, dont certains tendent à se rapprocher de niveaux de crise. Ces défis affectent également de manière significative l'agriculture. Pour ce secteur, les impacts des phosphates, des nitrates, de l'eau et du climat présentent des défis environnementaux majeurs. La préservation de la biodiversité, des paysages, le bien-être animal et l'utilisation d'antibiotiques sont également des éléments qui pourraient être ajoutés à la liste. Compte tenu de la multiplicité des défis et de la nécessité de respecter les engagements juridiques envers plusieurs objectifs de durabilité et de climat, une approche intégrée s'impose pour relever ces défis. En d'autres termes, il faut optimiser les politiques publiques. Dans le prolongement de son engagement envers l'Accord de Paris, le gouvernement néerlandais a pris des mesures en élaborant un accord national sur le climat (Klimaatakkoord). Afin de mieux comprendre les actions nécessaires à plus long terme (jusqu'en 2050), une étude particulière explorant différents scénarios a été publiée, dont les principaux résultats sont présentés dans cet article avec un focus sur le défi climatique. Cette étude suggère que l'élevage et des sols agricoles disposent encore d'un potentiel considérable pour réduire les émissions de gaz à effet de serre d'ici 2050, même à l'échelle actuelle du secteur agricole.

Klimawandel und Landwirtschaft: eine ganzheitliche Perspektive aus den Niederlanden

Die Niederlande sind mit einer Reihe an ernst zu nehmenden, miteinander verbundenen ökologischen und wirtschaftlichen Herausforderungen konfrontiert. Einige dieser Herausforderungen können tendenziell das Ausmaß einer Krise annehmen und betreffen auch die Landwirtschaft. Hier zählen Phosphat, Nitrat, Wasser und Klimafolgen zu den wichtigsten ökologischen Herausforderungen. Der Erhalt der Artenvielfalt und von Landschaften, Tierwohl und der Antibiotikaeinsatz sind ebenfalls Aspekte, die der Liste hinzugefügt werden könnten. In Anbetracht der zahlreichen Herausforderungen und der Notwendigkeit, die gesetzlichen Verpflichtungen zu mehreren Nachhaltigkeits- und Klimazielen einzuhalten, ist ein ganzheitlicher Ansatz zur Bewältigung dieser Herausforderungen erforderlich. Mit anderen Worten: Es besteht Bedarf an politischer Optimierung. Als Konsequenz aus ihrer Verpflichtung zum Pariser Abkommen hat die niederländische Regierung ein nationales Klimaabkommen (Klimaatakkoord) entwickelt. Für einen detaillierten Einblick in die längerfristig (bis zum Jahr 2050) erforderlichen Maßnahmen wurde eine Studie zur Untersuchung von verschiedenen Szenarien durchgeführt und herausgegeben. Deren Hauptergebnisse stellen wir im vorliegenden Artikel mit Fokus auf die Herausforderungen im Bereich Klima vor. Die Studie deutet darauf hin, dass es sowohl bei der Tierhaltung als auch bei den landwirtschaftlichen Böden noch ein erhebliches Potenzial gibt, die Treibhausgasemissionen bis zum Jahr 2050 zu reduzieren – selbst bei der derzeitigen Größe des Agrarsektors.