Joint Working Party on Agriculture and the Environment

DIGITAL OPPORTUNITIES FOR BETTER AGRICULTURAL POLICIES: INSIGHTS FROM AGRI-ENVIRONMENTAL POLICIES

ANNEXES

This document provides three annexes to the OECD report “Digital Opportunities for Better Agricultural Policies: Insights from Agri-environmental Policies”. It is a companion document to the main report.
Annex A provides ten case studies conducted to support this work.
Annex B provides a table defining types of agri-environmental polices used in this work.
Annex C provides an overview of the OECD questionnaire conducted to support this work.

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JT03449524
Note by the Secretariat

This document comprises three annexes for the report “Digital Opportunities for Better Agricultural Policies: Insights from Agri-environmental Policies”. This work was completed under 2017-2018 PWB item 3.2.3.1.5 New Policy Challenges from Emerging Technologies in Agriculture. This report considers how digital technologies can be used to support policies to improve agricultural sustainability within different stages of the policy cycle, drawing on ten detailed case studies and the results of a detailed questionnaire sent to OECD members on the use of digital technologies by agencies responsible for designing, implementing and monitoring agri-environmental policies.

The report and the accompanying annexes are authored by Gwendolen DeBoe and Marie-Agnès Jouanjean, of the OECD Trade and Agriculture Directorate. The ten case studies prepared in support of this report were drafted in collaboration with the following case study participants: Michele Barson (Australian Department of Agriculture and Water Resources), Anti Bleive (Estonian Agricultural Registers and Information Board), Ross Brennan (United States Environmental Protection Agency), Michael H. Cosh (USDA-ARS), Jan Gerrit Deelan (Agricultural Counsellor, Permanent Representation of the Kingdom of the Netherlands to the OECD), Johnny Gonzales (California State Water Resources Control Board), Stephen Hardy (CSIRO), Frans Lips (Ministerie van Landbouw, Natuur en Voedselkwaliteit), Richard McDowell (Our Land and Water New Zealand/AgResearch), Aard Mulders (Netherlands Ministry of Agriculture, Nature, Food Quality), Lisa Pearson (Land and Water Science Ltd.), Dimitris Petalios (CREVIS), Jodi Pontureri (California State Water Resources Control Board), Perry Poulton (CSIRO), Clint Rissman (Waterways Centre/Land and Water Science Ltd.), MS Srinivasan (NIWA), Brianna St Pierre (California State Water Resources Control Board), Dan Tindall (Remote Sensing Centre, Queensland Department of Environment and Science & Joint Remote Sensing Research Program), Catherine Tunis (United States Environmental Protection Agency), Oliver Vääntnõu (Cybernetica), Inger Wilms (BoerenNatuur). However, readers should note that lessons drawn from the case studies are the responsibility of the OECD authors and do not necessarily express the views of the case study participants or their affiliated organisations. The authors also gratefully acknowledge the organisations who responded to the questionnaire conducted in support of this report (for a full list, see Annex C).

This document was declassified by the Joint Working Party on Agriculture and the Environment in June 2019.
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Annex A. Case studies

Annex A brings together 10 case studies developed as background for the report “Digital opportunities for better agricultural policies: insights from agri-environmental policies”. Their purpose is illustrative rather than comparative.

The case studies focus on different types of digital technologies, and how they are being used or managed by public authorities, sometimes in co-operation with the research and private sectors. Together they highlight the diversity of use of technologies for policy making and implementation, as well as illustrating potential roles for governments in the development of a data infrastructure.

The case studies have been developed in co-operation with relevant public bodies, based on interviews of relevant stakeholders, and complemented by documents provided by participants as well as academic literature when possible. However, lessons from the case studies are the responsibility of the OECD authors and do not necessarily express the views of the case study participants. Case studies 1 to 7 were written by Gwendolen DeBoe, in collaboration with case study participants. Case studies 8 to 10 were written by Marie-Agnès Jouanjean, also in collaboration with case study participants.

The 10 case studies have been taken from six countries and regions: Australia (2), the European Union (1) Estonia (1), the Netherlands (2), New-Zealand (1), and the United-States (3). The country and region coverage was not intended to be comprehensive across all OECD countries, but was rather a factor taken into consideration when choosing case studies; the overall selection of case studies was made based on judgement by the OECD secretariat and was guided by the objective of including a diverse range of examples which serve an illustrative purpose relevant to the main paper. The intent is also not to provide a systemic review of public bodies initiatives in relation to the use of digital technologies for the design and implementation of agri-environmental policies; this more systematic view was obtained via the use of a Questionnaire designed for this (see Annex C). For comparative results, consult the questionnaire analysis.

Shorter versions of these case studies, focussing on the lessons learned, are incorporated into the body of the OECD report Digital opportunities for better agricultural policies: insights from agri-environmental policies.

The case studies are the following:

- **Case Study 1: New Zealand Our Land and Water National Science Challenge**: This case study provides a practical example of how digital tools can be used to improve understanding of nutrient sources and their attenuation pathways, and agriculture’s impacts on water quality outcomes and policy options for management of water quality impacts, as part of a complex national innovation initiative.

- **Case Study 2: Digital technologies for Dutch agricultural collectives**: This case study provides a practical example of how data management and transfer technologies can be used for the effective and efficient operation of collective governance mechanisms to that focus on achieving environment-climate-biodiversity objectives in agriculture. These technologies and their accompanying administrative and legislative arrangements enable achievement of these objectives.
in a way that considers the landscape as a whole while providing spatial and temporal flexibility for participating farmers and other stakeholders.

- **Case study 3: Gully erosion monitoring in Australia’s Great Barrier Reef catchments:** This case study provides a practical example of how remote sensing technologies and data or analytical products generated using these technologies can improve the effectiveness and efficiency of gully erosion and sediment control programmes.

- **Case study 4: Earth Observation initiatives for administration of the European Union Common Agricultural Policy:** The case study provides practical examples from the European context of how digital technologies can improve systems which pay farmers for producing ecosystem services.

- **Case study 5: Digital technologies applied by USEPA to achieve Innovative Compliance:** This case study provides a practical example of how digital technologies and data transparency tools can be used as part of a broader strategy to improve the flexibility and robustness of regulatory environmental programmes.

- **Case study 6: Digital innovations to facilitate farm level data analysis while preserving data confidentiality:** The case study objective is to show how recent innovations such as “confidential computing” can improve access to farm-level data for agricultural and agri-environmental policy or research, while appropriately maintaining data confidentiality and security. While recognising that there are many relevant innovations around the globe, this case study provides examples drawn from the experience of Australia’s Commonwealth Scientific and Industrial Research Organisation (CSIRO), a world leader in these emerging technologies.

- **Case study 7: Data transparency, digital technologies and California’s water quality coalitions:** This case study demonstrates how data regulations and coalition-based water quality monitoring regimes can be used to underpin collective governance mechanisms to address nonpoint source environmental impacts from agriculture. These mechanisms strike a balance between lessening information asymmetries and gaps on the one hand, and protecting sensitive information and reducing regulatory burden on the other.

- **Case study 8: Estonia e-government and the creation of a comprehensive data infrastructure for public services and agriculture policies implementation:** This case study illustrates how digital technologies can be used to improve the administration of government systems and the provision of public services, including in relation to agriculture. It provides the example of e-Estonia, an initiative by the Estonian government to facilitate citizen interactions with the state through the use of electronic solutions. It highlight some of the applications in the agriculture sector and for policy implementation.

- **Case study 9: Connecting the dots to create a data infrastructure: Insights from the National Soil Moisture Network (NSMN) in the United States:** This case study provides an example of a government, the initiative in the United States, which intends to address the fragmentation and heterogeneity of data coverage for the tracking of soil moisture. It combines data from satellite with the data captured by deployment of mesonet (State level mesoscale networks) for the ground validation to build a national inventory that can inform management and policy decisions.
Case study 10: Data infrastructure and the potential role of the government supporting the data infrastructure – Example of the Akkerweb in the Netherlands: The Akkerweb is an open platform for digital services for precision farming. This case study provides a practical example of how public-private partnership on an open data infrastructure can facilitate the creation and uptake of value adding services by the private sector, supporting productivity and sustainability in agriculture. Akkerweb is a foundation, founded by both Wageningen University and Research and a farmers’ association, Agrifirm.
Case study 1: New Zealand Our Land and Water National Science Challenge

Case study objective

The case study objective is to give a practical example of how digital tools can be used to improve understanding of nutrient sources and their attenuation pathways, and agriculture’s impacts on water quality outcomes and policy options for management of water quality impacts, as part of a complex national innovation initiative.

Context: a new approach to sustainable, productive agriculture in New Zealand

New Zealand’s Our Land and Water National Science Challenge (the Challenge) is a mission-oriented, government-funded, research and innovation programme, which aims to “enhance primary sector production and productivity while maintaining and improving our land and water quality for future generations”[^2]. The Challenge, which commenced in January 2016 and is ongoing, is comprised of three Research Themes[^3]:

1. Greater Value in Global Markets
2. **Innovative and Resilient Land and Water Use**
3. Collaborative Capacity

The second Research Theme (RT) – *Innovative and resilient land and water use* – is the primary focus of this case study. The goal of this RT is “to help land managers to grow the profitability and yield of productive land uses within the allowable environmental limits by providing widely applicable science and tools to understand the “off-farm” environmental risks associated with a specific area of land.” This goal is set within the context of New Zealand’s 2014 *National Policy Statement – Freshwater Management* (NPS-FM), which sets statutory requirements for freshwater bodies and requires Regional Councils to meet these objectives[^4]. This RT will “evaluate, model and assess land and water resources and the environmental, social, cultural and financial suitability of land use practices. [It] will look at new technologies, concepts and enterprises that enable individual and collective land and water users and regulators to best adapt to market signals, to derive optimal value


[^4]: Our Land and Water Revised Plan 2015, p.35. The NPS-FM is an overarching national policy for freshwater management, whose objective is “that the overall quality of freshwater within a region is maintained or improved and Regional Councils have to meet its statutory requirements. The NPS-FM links to the National Objectives Framework (NOF) that outlines the water quality objectives that Regional Councils have to meet, along with the proposed Environmental Reporting Bill increasing the demand for enhanced environmental monitoring and reporting.” (p.14)
chains and achieve their primary production targets within community and regulatory limits.” Thus, this RT will assist land managers, communities and regulators.

To achieve its goals, the RT is comprised of a number of research programmes (>NZD 1 million investment) and smaller projects (refer Table 1.1).

The Challenge as a whole envisages a new approach to fostering a primary agriculture sector that is both productive and sustainable; captured in the idea that “having the right enterprise in the right location at the right time will deliver the right outcome for individual property owners and catchment communities”. The Challenge aims to enable New Zealand to “move from considering land use capability (generally driven by production potential and other factors such as off-site environmental impact) to land use suitability where economic, environmental, social and cultural factors are considered together” (Our Land and Water National Science Challenge, 2015, p. iv).

Table 1.1. Research programmes and projects under the Innovative and Resilient Land and Water Use Theme of New Zealand’s Our Land and Water National Science Challenge

<table>
<thead>
<tr>
<th>Research programme/project</th>
<th>Objective</th>
<th>Challenge funding (NZD million)</th>
<th>Co-funding (NZD million)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sources and Flows</td>
<td>To understand the fate, transport and attenuation processes of key contaminants - nitrogen, phosphorus, sediment and microbes - within catchments and from catchments to receiving waters, in order to (i) support more informed decision-making on investment in land use activities; (ii) enable land managers and regulators to identify the critical contaminants that will result in environmental impact from specific land uses and locations, as well as acceptable limits of discharge to enable the most cost-effective and appropriate level of mitigation for their enterprise; and (iii) identify which contaminants have potential headroom(^5) to allow for increased production within environmental constraints, or where catchment re-design utilising low environmental footprint land use options are required.</td>
<td>3.15</td>
<td>0.2</td>
</tr>
<tr>
<td>Land Use Suitability</td>
<td>To help stakeholders in land use and management evaluate different approaches for sustainable production within the constraints posed by environmental objectives (also expressed as ‘managing within limits’).</td>
<td>2.75</td>
<td>4.8</td>
</tr>
<tr>
<td>Next Generation Systems</td>
<td>To provide a framework to enable critical assessment of transformational land use systems and use science from across the Challenge to address barriers to adoption of new systems. Next generation systems is designed to work with the land-based primary sector in enabling transformative innovation under nutrient limiting conditions.</td>
<td>2.0</td>
<td>-</td>
</tr>
<tr>
<td>Assessing the Yield and Load of Contaminants with Stream Order</td>
<td>To determine the load (kg/yr) of catchment contaminants that come from large or small streams, and if excluding livestock from large streams (&gt; 1-m wide, &gt;30-cm deep) in flat catchments used for pastoral grazing would substantially decrease the load of catchment contaminants.</td>
<td>0.05</td>
<td>-</td>
</tr>
<tr>
<td>Interoperable Modelling</td>
<td>To develop a modelling system populated with models which draws on national datasets and is implemented in an interoperable modelling framework. This modelling system will be used nationally for integrated and spatial assessment of economic, production and environmental implications of land use and land use change.</td>
<td>0.9</td>
<td>2.66</td>
</tr>
<tr>
<td>Innovative Agricultural Microbiomes</td>
<td>To provide a better understanding of microbiome structure and environmental function, and the implications for (dairy) farm system productivity and sustainability.</td>
<td>1.8</td>
<td>0.2</td>
</tr>
<tr>
<td>Faecal source tracking</td>
<td>To identify the potential sources of faecal contamination impacting waterways to ensure appropriate and targeted mitigation steps are implemented for appropriate land use and to reduce stakeholder risk.</td>
<td>0.25</td>
<td>0.08</td>
</tr>
</tbody>
</table>

Cascade of soil erosion to rivers
To test the feasibility of developing physically based equations of soil erosion and sediment transport at the landscape scale.

Physiographic Environments of New Zealand (PENZ)
The physiographic approach seeks to explain ‘how’ and ‘why’ shallow groundwater and surface water quality varies across different landscapes, even when there are similar land uses or pressures in a catchment. This project provides a map that explains these drivers of water quality across New Zealand.

Benign denitrification in groundwater
To create a rapid and cost effective technique to measure and map complete benign subsurface denitrification hotspots in New Zealand agricultural catchments.

Measuring Groundwater Denitrification
To develop and validate a methodology for measuring dissolved neon. This project enables the concentration of excess nitrogen to be derived, allowing for the extent of denitrification in groundwater systems to be quantified.

Note: a Challenge programmes and projects are supported by approximately NZD 12 million in co-funding from government, industry and the science sector. This table lists Challenge funding and co-funding separately. The proportion funded by Challenge funding versus co-funding varies across programmes and projects. For example, the interoperable modelling programme receives only NZD 0.9 million because it has NZD 2.75 million in co-funding.

1. McDowell et al. (2018, p. 215) define “headroom” as follows: “The receiving environment has headroom when the total delivered load is less than the maximum acceptable load (i.e. the ratio is less than one).”


Use of digital technologies in the Innovative and Resilient Land and Water Use Research Theme

The problems
The key goal of the Innovative and resilient land and water use RT is to move to a Land Use Suitability (LUS) framework for New Zealand agriculture. Existing efforts to manage land for (environmental) sustainability are based on land-use capability (LUC) classifications. LUC classification defined as “a systematic arrangement of different kinds of lands according to those properties that determine its capacity for long-term sustained production” (Lynn et al., 2009, p. 8). Data requirements for LUC classification therefore relate to on-site physical and environmental characteristics. In contrast, the Land Use Suitability (LUS) classification which the Challenge aims to produce integrates “information about the economic, environmental, social and cultural consequences of land use choices” (McDowell et al., 2018), and thus requires substantially more, and different, data than was needed previously. Thus, achievement of this Research Theme’s objective requires a number of different information gaps to be filled. Key gaps include:

- Information about natural processes (e.g. nutrient and other contaminant pathways), including their spatial and temporal characteristics
- Information about how producers and other land managers respond to incentives (both policy and other incentives)

These information gaps also prevent the targeting of existing policies to take into account local contexts. For example, whereas many researchers note that nutrient or other contaminant loss factors (from agriculture and other sources) vary widely depending on location-specific factors, current implementation of New Zealand’s National Policy Statement of Freshwater Management (2014) applies uniform contaminant loss factors “to

6 Refer to Chapter 2 of main report, which presents the conceptual framework for analysis and identifies that information gaps, information asymmetries, transactions costs and misaligned incentives as sources of fundamental problems for agri-environmental policies, which digital technologies can help ameliorate or overcome.
all areas of land as there are not the tools or frameworks available to link contaminant losses from different parts of a landscape to different levels of water quality impacts downstream.7

Further, the existing research landscape is characterised by **fragmented and asymmetric information**: often, data sets and digital modelling tools are accessible only by the researchers who work with them directly. This leads to duplication, confusion over the role of different models and research efforts, and impedes effective translation of research efforts into change “on the ground” (McDowell et al., 2017[7]). In addition, licensing issues with some of the datasets mean data sharing between researchers could be difficult. Case study participants observed that in a collaborative setting, the researchers can settle for a common minimum data that is accessible to all, but which may not be the most up-to-date dataset.

**Digital solutions**

The Challenge is making use of a number of digital tools to address the information gaps and asymmetries identified above. In some cases, pre-existing tools are being repurposed to help achieve Challenge objectives; in other cases, Challenge funding is being used to enhance pre-existing tools or build new ones. These tools constitute an important part of Challenge activities, but it is important to recognise that they are being developed and used alongside other (non-digital) activities.

Table 1.2 provides a description of the main digital tools being developed or enhanced under the Innovative and Resilient Land and Water Use Research Theme, using the classification of digital technologies presented in the project main report (refer Table 2.1 in main report). This table includes several tools which are being advanced through co-innovation (see Box 1.1) at the same time as the Challenge tools and which support the Challenge research programmes, but which do not receive Challenge funding. This table does not provide an exhaustive list of all digital tools developed using Challenge funding, as the project is ongoing.8

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Box 1.1 Our Land and Water co-innovation approach

A central tenet underpinning the Challenge is that its objectives will not be achieved unless Challenge participants and stakeholders work together collaboratively (Our Land and Water, 2018, p. 4[4]). Recognising that there is insufficient documented evidence of the benefits of collaboration, the Challenge includes a range of specific efforts to measure these benefits and advance understanding of how collaborative processes can be improved.\(^1\) The Challenge implements a new way of working, termed “co-innovation”, which replaces the existing “funder-provider” model. Co-innovation is defined as “individual land managers, primary production sectors, \(iwi\)^2 communities, policymakers and scientists all working collectively to identify priority issues and create enduring solutions.” (Our Land and Water National Science Challenge, 2016, p. 4[8])

Co-innovation involves a much closer relationship with stakeholders than existing approaches. The intent is that this closer relationship will produce research that is fit-for-purpose, relevant and will be used and championed within stakeholder networks.

The Challenge defines several different dimensions (and example metrics) of co-innovation:

- **Co-design**: research questions are developed with stakeholders and signed off as relevant. The Challenge maintains a record of co-designing all programmes with stakeholders.
- **Co-development**: this generally involves scientists physically co-locating with stakeholders and stakeholders co-investing. Across the wider research landscape we have seen an increase in the frequency of collaboration by 66% (from 1.6 institutes per research programme in 2015 to 2.6 in 2017), while Challenge-funded programmes maintain an average of 5.3 collaborations.
- **Co-production**: investment in and extension of outputs into outcomes is sustained by stakeholders co-authoring Challenge documents. During the first two years of the Challenge, more than 50% of academic outputs were co-authored with stakeholders.
- **Co-innovation**: outcomes are promulgated by stakeholders e.g. a close working relationship with science enables a stakeholder to reach sensible water quality limits

The Challenge aims to test the hypothesis that using co-innovation in science can lead to quicker, more robust and enduring outcomes. In particular, it aims to halve the time taken for an idea to be at its maximum level of use from 16 years (Kuehne et al., 2017[9]).

However, some participants noted that because co-innovation is inclusive and deliberative, the process may in fact take longer compared to a situation where researchers develop a solution with little to no input from users and then “push” the solution to users. This raises a question about whether there is a trade-off between designing solutions which are “better” (in the sense of being more robust, enduring or fit-for-purpose) versus “quicker”, and how to measure these different dimensions in order to evaluate and compare different innovation approaches. The Challenge will also be testing this aspect of co-innovation.

Notes: 1. See in particular work done under the third Challenge Theme—Collaborative Capacity.
Table 1.2. Digital tools developed under the *Innovative and Resilient Land and Water Use* Research Theme

<table>
<thead>
<tr>
<th>Digital tool</th>
<th>Challenge research programme</th>
<th>Brief description of tool</th>
<th>Data used by tool (if applicable)</th>
<th>Status as of September 2018</th>
<th>Benefits of tool</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Data collection tools</strong></td>
<td></td>
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<td></td>
<td></td>
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<tr>
<td>Land, Air, Water Aotearoa, Ministry for the Environment</td>
<td>National register of measures, interoperable models and data ecosystem white paper</td>
<td>Metadata standards to facilitate the supply and use of environmental data between Challenge modelling tools and central and regional government repositories</td>
<td>National coverage of point data for land and water quality parameters</td>
<td>The Challenge provides advice and funding to continue this work to ease the handover of Challenge modelling and tools</td>
<td>To steward the Challenge's modelling and tools and create a legacy beyond the life of the Challenge.</td>
</tr>
<tr>
<td><strong>Digital analytical tools</strong></td>
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<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Framework</td>
<td>Sources and Flows</td>
<td>Framework provides a conceptual link between contaminant source, transport from land to water via surface and subsurface pathways and attenuation during transport processes. The Framework is placed within a hydrology sub-framework that is applicable to all contaminants. The Framework is agnostic to spatial and temporal scales.</td>
<td>National scale climate, flow and water quality data</td>
<td>The conceptual framework development has been completed. Three contrasting case study catchments have been chosen for testing the robustness and applicability</td>
<td>The biophysical Framework allows linkages to other non-biophysical frameworks and components such as cultural, economic and social. This linkage shall be piloted in one of the case study catchments in 2018-19 to allow the community to envisage the perceived values of such linkages. Because they are not bundled into a tool, the Framework layers could be used and manipulated to suit the stakeholder and end-user needs.</td>
</tr>
<tr>
<td>MitAgator</td>
<td>Aligned programme <em>a</em></td>
<td>A spatial farm tool that maps critical source areas of contaminant losses to water and provides estimates of the cost-effectiveness of measures to mitigate their loss</td>
<td>National scale soil and climate data. Farm management data provided by industry standard model – Overseer (<a href="http://www.overseer.co.nz">www.overseer.co.nz</a>)</td>
<td>Released July 2018 (<a href="http://www.ballance.co.nz/Mitagator">www.ballance.co.nz/Mitagator</a>)</td>
<td>Enables farmers to estimate the likelihood and cost-benefit of reaching an allocation limit.</td>
</tr>
<tr>
<td>Digital tool</td>
<td>Challenge research programme</td>
<td>Brief description of tool</td>
<td>Data used by tool (if applicable)</td>
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<td>------------------------------------------------------------------------------------------</td>
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</tr>
<tr>
<td>National physiographic classification</td>
<td>Physiographic Environments of New Zealand (PENZ)</td>
<td>The main outputs will be: 1. Classed process-attribute GIS layers that depict the spatial coupling between process signals in water and landscape attribute gradients. GIS layers will include:  • Hydrological Process-Attribute Layer • Redox Process-Attribute Layer • Physiographic Map (combined hydrological and redox process layers) 2. A web-based interface for farmers and industry.</td>
<td>• National scale landscape attribute data (from pre-existing GIS layer for geology, soil, topography, climate data, land cover, water flow and quality data) • Finer scale soil mapping, LIDAR, radiometric imagery data to augment national scale data</td>
<td>A physiographic classification (Physiographic Environments of New Zealand) is currently being created for 7 regions in NZ. The web-based interface for farmers and industry to access physiographic science is initially being developed for NZ’s Southland region as part of a government grant. Development and design of the web-based interface is being guided by farmers, industry groups and extension staff.</td>
<td>Provides an opportunity to target and implement mitigations that are environmentally- and cost-effective by explaining, at the process level, ‘how’ and ‘why’ water quality and composition vary under similar levels of land use intensity.</td>
</tr>
<tr>
<td>Land Use Suitability digital tool</td>
<td>Land Use Suitability</td>
<td>A concept and prototype GIS-based tool for analysing land-water systems. The first application of the concept examines productivity within environmental constraints and produces three indicators:  • Productive potential: a classification for what a land parcel can do and the value it can return  • Relative contribution: how much contaminant a land parcel is reaching a site of impact, relative to others, after taking into account attenuation  • Pressure: whether or not a water body is exceeding the allocated load (as set by an objective)</td>
<td>National scale climate, water flow and quality and land use capability data.</td>
<td>Concept has been published and a prototype tool has been developed and tested in one region (Southland). The tool will be extended nationally in 2019, and augmented with other attributes (e.g. social and cultural).</td>
<td>Provides an objective measure of land use relative to an environmental objective at a land parcel and catchment scale. Informs policy that seeks to address what environmental objectives can be achieved beyond implementing measures to reduce losses, but sustain, the current (and potentially underperforming) land use.</td>
</tr>
<tr>
<td>OVERSEER science and capability</td>
<td>Aligned project under this research theme</td>
<td>Enhancements to NZ’s OVERSEER® nutrient budget model (<a href="http://www.overseer.co.nz">www.overseer.co.nz</a>), the industry standard for estimating N and P losses from different enterprises.</td>
<td>Farmer, consultant, or researcher inputs are augmented by nationally available databases on soil and climate.</td>
<td>Model was first developed in the mid 1990’s and is freely available.</td>
<td>This work will continue to develop new science for incorporation into NZ’s OVERSEER® model. The Challenge is specifically funding work to make Overseer interoperable with other catchment scale models.</td>
</tr>
<tr>
<td>Digital tool</td>
<td>Challenge research programme</td>
<td>Brief description of tool</td>
<td>Data used by tool (if applicable)</td>
<td>Status as of September 2018</td>
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</tr>
<tr>
<td>River Environment Classification digital stream network layer</td>
<td>Supports Challenge research but is not funded by Challenge</td>
<td>Upgrades existing River Environment Classification digital stream network GIS layer to significantly improve the spatial definition of the network.</td>
<td>Point elevation data and remote sensing information from LiDaR surveys</td>
<td>The first iteration of this new network layer was completed for both North and South Islands and made publicly available in June 2018.</td>
<td>Facilitates development of the NZ Water Model, a sophisticated computer model framework that will enable users to accurately predict how much freshwater is available, where it has come from, and how quickly it moves through New Zealand catchments.</td>
</tr>
<tr>
<td>National Catchment-scale Source-Delivery-Attenuation modelling</td>
<td>Used by Sources and Flows but was developed prior to the Challenge</td>
<td>A national scale, scenario-based water quality modelling tool that allows modelling of contaminant (N, P, and sediment) loads from catchments to water bodies.</td>
<td>National scale water quality data from river, farm scale data from a farm scale model OVERSEER</td>
<td>The model has been applied to entire NZ to understand critical knowledge gaps across the country.</td>
<td>Tool allows identifying areas where insufficient information exists in characterising land management and its impact on water quality.</td>
</tr>
<tr>
<td>Data management tools</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Interoperable modelling framework</td>
<td>Interoperable Modelling</td>
<td>Nationally-recognised modelling platform for assessment of environmental, production and economic implications of land use and land use change. The platform (Deltashell) will be populated with models and national datasets.</td>
<td>Models are to use the best available data from central and regional government (see Land, Air, Water, Aeotearoa)</td>
<td>Programme initiated.</td>
<td>Provides a modelling framework that can be used for a variety of purposes, including regulatory limit setting, land-water management, and contaminant accounting at farm and catchment scales. This will reduce costs, duplication and uncertainties caused by using different models for different purposes, and foster collaboration and a shared understanding of environmental and economic impacts of different land use options.</td>
</tr>
<tr>
<td>Digital communication tools and service delivery platforms</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Land, Air, Water Aeotearoa</td>
<td>National register of measures</td>
<td>Hub and advisory service that displays and explains the state and trends associated with air, land and water quality data from regional authorities (<a href="http://www.lawa.org.nz">www.lawa.org.nz</a>)</td>
<td>All data collected by regional authorities, limited in the first instance to water quality, but to be extended to other domains when data availability and quality allows.</td>
<td>Initiated June 2018. Initial scoping to June 2019 with the intention of it being augmented from July 2019 with a list and location of catchment management groups who have or are using measures to mitigate the effects of land use on water quality, the performance of measures and advice on what measure to use to meet an environmental objective.</td>
<td>Stakeholders (farmers, industry, regulators) will have greater confidence in implementing measures to improve water quality to meet a limit. Advice will emphasise what, where and when to implement measures.</td>
</tr>
</tbody>
</table>
Notes: a Aligned programmes are those that offer support and significantly advance the Challenge mission. Aligned programmes/projects are identified through the Research Landscape Map and formally documented vis-à-vis their milestones/deliverables and to what key performance indicator they advance.

b HPAL provides landscape controls over: 1. Water source (where does the water in a stream or aquifer originate from); 2. Recharge mechanism (the broad scale mechanism/process by which water reaches an aquifer or stream); 3. Water pathway (fine scale mechanism/process controlling the pathway water takes – bypass flow, overland flow, lateral drainage and deep drainage).

c RPAL for soil and aquifer reduction potential controls: 1. Denitrification; 2. The solubility, leachability and mobility of redox sensitive species.

d The output to produce a web-based interface is funded by The Ministry for Primary Industries through the Sustainable Farming Fund. This is aligned with the OLW PENZ project which delivers the science output while the web-based interface aims to make the science (physiographic map) more accessible to farmers and primary industry groups to inform farm management decisions.

e Hydrochemistry and water quality data for surface and groundwater (PENZ test set, LAWA); Climate (Temperature, precipitation, ispscape); Hydrology (REC); Soil (Fundamental Soil Layer, S-Map); Geology (QMap, NZLRI); Topography and Elevation (8m Digital elevation model, LiDAR); Land Cover (LCDB4.1); and additional regional datasets (Land use, Radiometric, soil chemistry).

f Northland, Auckland, Waikato, Bay of Plenty, Manawatu-Wanganui, Canterbury, and Southland.

Source: Authors, based on information supplied by case study participants, Our Land and Water National Science Challenge (2016[8]) and Rissmann et al. (2018[10]).
Managing data and interaction between digital tools: a vision for a data ecosystem

The many and varied research projects under the Challenge as a whole, and within the Innovative and resilient land and water use RT specifically, are producing a “growing diversity, complexity and volume of data” (Medyckyj-Scott et al., 2016[11]). From the start of the Challenge, it was recognised by the Challenge Chief Scientist and Leadership Team that gathering this data into a shared “data ecosystem” is one of the greatest sources of potential value added for the Challenge as a whole. In 2016, a group of experts from the New Zealand public service and the research sector collaborated to produce a “white paper” on the design of this data ecosystem. The data ecosystem is explained as “a system made up of people, practices, values and technologies designed to support particular communities of practice [in which] data is valued as an enduring and managed asset with known quality” (Medyckyj-Scott et al., 2016, p. V[11]) and defined (Medyckyj-Scott et al., 2016, p. 5[11]) to encompass:

- Policies regarding data management planning, data custodianship and curation, legal frameworks, and the use of externally sourced data;
- Procedures and processes to execute those policies and manage data;
- A data governance framework and organisational structures;
- Engagement with data consumers and stakeholders; and
- Technology platforms that will support data collection, storage, description, analysis, linking, delivery and curation.

The data ecosystem is proposed to be “supported, enabled and facilitated by a federated infrastructure in which data may be collected from traditional sources and new technologies, curated, published, analysed, modelled, linked, used and reused but accessed through a single point of access, from its authoritative point of origin, with discovery and visualisation tools” (Medyckyj-Scott et al., 2016, p. 21[11]).

Efforts to date have focused on developing a standard for metadata. However, the Challenge recognises that the issue will cost more than it can afford and that the solution must endure beyond the life of the Challenge (due to end in 2024). Therefore, the Challenge has engaged with central government agencies to act as repositories for data and modelling efforts, such that outcomes can be driven from the legacy of Challenge science.

Lessons learned

Lesson 1: Multi-dimensional integration of digital and other tools is needed to ensure efficiency and effectiveness.

Interoperability⁹ is an important consideration when building new digital tools or enhancing existing ones, and has long been identified as a key factor for efficiency and effectiveness. However, this case study demonstrates that more is needed than interoperability to ensure efficiency and effectiveness: digital technologies need to have clear roles with definable “added value” relative to other tools and relative to policy and programme objectives. This is encapsulated in the notion of making digital tools integrated,

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⁹ Interoperability can be defined as “the ability of two or more systems or components to exchange information and to use the information that has been exchanged” (Geraci, 1991[68]).
both with other tools and with other programmes or initiatives than the one under which they are developed. Dimensions of this integration include:

- clearly articulating how a new tool complements existing tools, including by considering whether a policy or programme objective can be achieved via leveraging an existing tool (potentially with enhancements) versus building a new tool;
- acknowledging that digital technologies are only one part of a broader solution;
- acknowledging that multiple digital tools are needed to accomplish complex policy objectives (e.g. models at different timescales, digital platforms to enable different users to use the same data or model for different purposes, etc.);
- considering potential uses of technologies that are broader than the current programme or initiative, and what design features will help ensure the re-usability of digital tools (in addition to re-use of data).

Case study participants identified two institutional design features that were instrumental in assisting the Challenge to achieve this integration:

- The co-innovation approach: as outlined in Box 1.1, the Challenge uses a co-innovation approach which actively includes a diverse range of stakeholders, right from the beginning of project design and throughout projects. This enables the relevance of research questions and likely outputs to be tested ‘up front’. It also increases the ability of Challenge participants to identify what type of new tools might be needed (e.g. digital tools or other tools), whether new tools are genuinely additional to existing tools (i.e. because creators and users of existing tools are included in the design process), and how different tools relate to each other.

- The data ecosystem ‘white paper’: the question of ‘[w]hat are the best data structures for land and water information to achieve the Challenge Mission?’ was actively considered from the outset of the Challenge. This helped ensure that all project proposals, including proposals for new digital tools, actively considered both existing and recommended data structures and existing data tools. As part of this process, the data ecosystem team conducted a collaborative workshop in 2015 (i.e. before the formal commencement of the Challenge) about digital tools to ensure stakeholder’s experiences with existing tools, particularly in relation to challenges, were taken into account (Medyckyj-Scott et al., 2016, pp. v, 11[11]).

Lesson 2: Monitoring and modelling should be viewed as complementary.

Often, monitoring and modelling happen as two separate streams of work, and modelling is often described as being needed in the context of incomplete information. This implies that modelling is only needed because of data deficiencies; that is, that monitoring and modelling are substitutes.11

In many cases, data gaps are likely to persist: monitoring of all physical variables of interest is unrealistic, despite advances in sensors, Internet of Things devices (e.g. “smart” agricultural machinery) and remote monitoring technologies which enable much broader

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10 Table 3 in Medyckyj-Scott et al. (2016, p. 11[11]) enumerates existing digital tools that the Challenge will interact with.

11 In particular, discussions of the use of modelling to support water quality policies for agriculture often centre on the notion that nonpoint sources (including agriculture) are sources for which it is not possible or prohibitively costly to measure and attribute emissions to particular sources (farms).
physical monitoring at lower cost than previously. Therefore, there will still be a need for models to attempt to “bridge” these gaps.

However, even if all necessary physical measurements could be obtained via monitoring, modelling may still be needed for a variety of functions, such as attributing physical impacts to non-physical drivers (particularly to policy drivers, so that policies can be evaluated), and modelling future scenarios to make ex ante policy assessments and improve planning.

Thus, modelling and monitoring should be viewed as complementary: modelling both uses data and allows for analysis in the absence of data.

Lesson 3: Ensure new digital tools don’t create new information asymmetries.

While the Challenge aims to produce a range of digital tools and information products which address existing information gaps, there is also the need to develop digital tools and effective stakeholder engagement strategies to ensure that production of new knowledge does not inadvertently produce information asymmetries. (This could potentially occur, for example, if only researchers involved in creating new knowledge or tools had access to them. The Challenge acknowledges this risk and addresses it via its co-innovation approach.

Lesson 4: Creation of dynamic, updatable digital tools can lessen the need to “reinvent the wheel” and better match users’ needs.

Reflecting the dynamic nature of many factors relevant to land management decisions, there is strong demand for up-to-date information. Previously, many tools were relatively static, making them less useful and prompting periodical attempts to “reinvent the wheel” (to make tools which better suit users’ needs, which may have changed). Therefore, tools that can allow for rapid update of information better match demand for information, and as such are likely to be used more, both now and in the future.

Lesson 5: Embrace different levels of Data Management Maturity to fit different contexts.

There are different levels of Data Management Maturity (DMM); it may not be necessary to advance all (or any) participants to the highest level of data management in order to achieve programme objectives. Also, it will take time to progressively move through the different levels of DMM. Strategic planning for transitioning through these levels (including planning for different stakeholders—whether individuals or organisations—to move through levels at different speeds) can be helpful for: (i) identifying the current situation (i.e. which participants are at which level), (ii) identifying which level(s) participants eventually need to reach for the programme or policy goal to be achieved, and (iii) improving the overall level of maturity while still allowing for flexibility and not imposing too high transition costs.

It is also important to recognise that moving towards more advanced levels of DMM may require attitudinal change. For example, the Challenge’s Data Ecosystem white paper (pp. 16, 29) identified that “experience shows that one of the major obstacles in the cultural

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12 Data Management Maturity (DMM) is a concept and framework for analysing institutional capacity to manage and make beneficial use of data assets. The DMM framework assesses data management practices in six key categories that helps organisations benchmark their capabilities, identify strengths and gaps, and leverage their data assets to improve business performance. See Medyczkyj-Scott et al., 2016([11]) and https://cmmiinstitute.com/data-management-maturity, accessed September 2018.
change is the view that data belongs to “me” and that it is not treated as an asset”. The authors concluded that “it is unlikely that maturity in handling data will emerge if in other ways participants lack a strong sense of community.”

Lesson 6: Ensure initiatives generate “additional” benefits by using a mix of old and new technologies.

Digital technologies have been in this case study used both to improve and enhance the functionality of existing analytical systems (e.g. upgrading the NZ Water Model), and to provide wholly new tools (e.g. LUS classification and Physiographic Environments of New Zealand GIS layers) that support decision-making process that were not previously possible. This enables the Challenge to avoid duplication and “reinventing the wheel”, while still ensuring that the tools are fit for purpose. This requires a thorough understanding of the existing analytical tools.

Lesson 7: Digital tools can be used to foster collaboration and overcome traditional roadblocks created by conflicting views and values.

Development of new digital tools often requires greater collaboration between different individuals and organisations, and across disciplines. Also, there needs to be strong links between new or enhanced tools developed within the initiative (in this case, within the Challenge) and other tools (e.g. NIWA digital stream network layer).

Digital tools are being successfully used to help parties with different interests and incentives to build consensus. For example, the OVERSEER® nutrient model, which is being enhanced under the Challenge and aligned programmes (e.g. to be made spatially explicit by MitAgator), has been developed using co-innovation and can be scrutinised by all interested parties. It functions as an “authoritative point of truth”, but is able to be updated with the latest available science and incorporate innovations (e.g. new data sources from new sensor technologies).

Lesson 8: Digital tools can enable new information-rich policy paradigms rather than simply improving the granularity of existing information-poor paradigms.

Many existing approaches to land use planning and managing environmental impacts are fundamentally based on a recognition that there are substantial information gaps and that assumptions are needed to bridge those gaps (Macey, 2013[12]). Land use capability (LUC) planning is one important example of these existing approaches. While the LUC approach provides “an indicator of the productive versatility of land parcels for a range of land uses and identifies key constraints such as erosion” (McDowell et al., 2018[2]), the focus is on determining what a given land parcel is capable of producing. This approach does not explicitly account for spatial linkages or for policy objectives such as objectives relating to downstream receiving water bodies. Because information on aspects such as nutrient transfer pathways and landscape attenuation capacity has been missing, existing watershed management policies tend to be based on LUC assessments and generally apply uniform approaches to different land-use types. While improved data can help these approaches to become more granular and allow for some degree of targeting (e.g. to focus mitigation or remediation efforts on areas where erosion potential is highest), it is difficult to explicitly take into account complex spatial and dynamic relationships within the LUC framework.

Digital tools such as those being explored in the Challenge can enable new approaches such as the land-use suitability (LUS) approach which are able to explicitly account for these complex spatial and dynamic relationships. Such holistic approaches, while still in their infancy, hold out the promise of designing policies which take into account a much greater
degree of complexity, including the ability to evaluate synergies and trade-offs between multiple policy objectives.

References


Case study 2: Digital technologies for Dutch agricultural collectives

Overview

This case study provides a practical example of how data management and transfer technologies can be used for the effective and efficient operation of collective governance mechanisms that focus on achieving environment-climate-biodiversity objectives in agriculture. These technologies and their accompanying administrative and legislative arrangements enable achievement of these objectives in a way that considers the landscape as a whole while providing spatial and temporal flexibility for participating farmers and other stakeholders.

Context: the policy environment and the Dutch collective approach

The EU Common Agricultural Policy (CAP) is the key legislative instrument governing payments made to Dutch farmers. Historically, national paying agencies have administered payments based on claim applications made by individual farmers. In 2014, the EU Rural Development Regulation (Regulation (EU) No. 1305/2013, Article 28(2)) provided for agri-environment-climate payments (one type of payment under Pillar II of the CAP) to be made to groups of farmers or groups of farmers and other land-managers, in addition to paying farmers individually.

In 2016, the Dutch government introduced a new scheme such that individual applications are no longer possible in the Netherlands; all applications must be lodged by an agricultural collective (Netherlands Ministry of Economic Affairs, 2016[13]). The government considered that the collective approach would:

- foster a “better-targeted and cross-farm approach”, focused on creating good habitat conditions for rare species and regional water quality protection, rather than pursuing farm-level commitments (Mulders, 2018[14]). The government considers this landscape approach is needed to address declines in farmland biodiversity (individual applications could be “detrimental to regional goals”);
- provide “greater flexibility in terms of the content of conservation activities, their exact location and their financial compensation”;
- be simpler and less error-prone than administration based on individual applications; leading to reduced costs and improved compliance; and
- be consistent with the existing social structure in the Dutch agriculture sector which “has a long tradition of agri-environment cooperatives”.

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13 Regulation (EU) No. 1305/2013, Article 28(2): Agri-environment-climate payments shall be granted to farmers, groups of farmers or groups of farmers and other land-managers who undertake, on a voluntary basis, to carry out operations consisting of one or more agri-environment-climate commitments on agricultural land to be defined by Member States, including but not limited to the agricultural area defined under Article 2 of this Regulation. Where duly justified to achieve environmental objectives, agri-environment-climate payments may be granted to other land-managers or groups of other land-managers.
In practice, this approach works as follows:  
- The **province government** contracts with individual cooperatives for selected agri-environmental targets over a 6-year period. Both **national and provincial governments** participate in the definition of the targets. The cooperatives are the beneficiaries of CAP subsidies. The Paying Agency undertakes official EU-required controls (administrative and financial checks), and pays the subsidy to the cooperatives.  
- The **cooperatives** contract with individual farmers for the provision of conservation targets, and develop guidance for individual payments and for the “distribution” of any penalties imposed on the cooperative in the event that the targets specified in the contract between the cooperative and the Paying Agency are not met. The cooperative works with farmers as well as other stakeholders such as conservation organisations to both decide on and deliver the conservation activities which will deliver on the targets. The cooperative also takes care of accounting, annual reporting (to the Paying Agency) and controls for individual contracts with farmers (e.g. on-the-spot-checks).  
- An umbrella organisation, **BoerenNatuur**, provides guidance and technical support to the 40 agri-environmental cooperatives. In particular, **BoerenNatuur** has developed digital platforms – described below – which the collectives use to administer contracts and payments, and to track the progress of individual conservation efforts that contribute towards the overall targets. This digital platform is directly linked to the digital platform of the paying agency.

**Use of digital technologies to support the effective and efficient operation of the collectives**

**The problems**

In order to achieve the vision for the collectives, a number of technical and administrative challenges needed to be solved:

- One important aspect of achieving **flexibility** is to design the administrative system and the payment rules to be able to “follow nature”. This requires rules and administrative procedures to be specified with reference to a date range or to when natural events (e.g. movement or nesting of birds) occur, rather than with reference

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14 For a detailed description of roles and responsibilities, see The Netherlands Ministry of Economic Affairs (2016[13]).

15 Cooperatives are responsible for: administration of farmer participants; digital registration the type of management on the land parcels of the participants (practically speaking: draw management unit on map and link to management activities/package); reporting of completed management activities from participants during the year; inspection of realization of management activities; preparation of collective claim (to be submitted to the Paying Agency); preparation of payment justification; payments of farmer participants. See [https://www.boerennatuur.nl/english/](https://www.boerennatuur.nl/english/), accessed May 2018.

to specific dates. In turn, this requires high resolution data on where and when the relevant natural events occur, as well as the ability to track individual actions (e.g. on-farm practices) accurately in space and time.

- Another important aspect of achieving flexibility at the local level is to recognise that EU rules may not be similarly flexible, and therefore to design a system which allows local flexibility while still “fitting in” with EU requirements. This introduces the risk that local flexibility will not “fit in”, which in turn requires additional risk mitigation mechanisms such as buffers between the maximum payment the paying agency is allowed to pay according to EU rules and the actual payment the collective asks for.

- To achieve the desired “cross-farm” or landscape approach, the system needs to be able to track all individual efforts and assess the aggregate effect, and enable an interactive regional planning process whereby regional objectives are set taking into account individual actions, as well as vice versa.

Conceptually, these challenges relate to addressing information gaps and creating coordination and risk management mechanisms between: (i) different actors who may have misaligned interests; (ii) different scales which may have different levels of flexibility and over which objectives might differ; and (iii) different legal frameworks which may (without these mechanisms) be inconsistent.

The solutions: SCAN-ICT—an IT system for the collectives

To address these challenges, the Dutch collectives are developing a system of digital technologies (SCAN-ICT, Mijnboerennatuur.nl, and Schouwtool). These tools interface with the digital platforms of the Dutch paying agency, for example the Dutch Land Parcel Identification System (LPIS).17

The SCAN-ICT was developed and built by SCAN (a foundation of collectives in agri-nature management, established to prepare the implementation of the collective AECM), as an assignment from the Dutch government (both Ministry and provinces).

Ownership of the digital platform lays at the 40 collectives together, working together in BoerenNatuur. It is obligatory for the collectives to make use of the SCAN-ICT. The SCAN ICT contains:

- Administration and contracts for farmer participants;
- Digital registration of the type of management on the land parcels of the participants (practically speaking: draw management unit on map and link to management activities or package)
- Reporting of completed management activities from participants during the year, including notification to be made to the paying agency;
- Preparation of the management plan on a landscape and parcel level;
- Preparation of the collective claim for all the parcels in a habitat;
- Preparation of payment justification for all the parcels in a habitat;

17 “A Land Parcel Identification System (LPIS) is an IT system based on aerial or satellite photographs recording all agricultural parcels in the [European Union] Member States. It is a key control mechanism under the Common Agricultural Policy (CAP) designed to verify eligibility for area-based subsidies” (European Court of Auditors, 2016[70]) Note there is legal obligation for the LPIS to be maintained by the Paying Agency; in part this provides motivation for the collectives to have a separate ICT system, even though this duplicates some of the LPIS data.
Payments of farmer participants.

Due to the direct link with the digital platform at the paying agency, SCAN-ICT makes it possible to change parcels and management activities on a short notice, without losing controllability requirements as a result of EU legislation. Further, it ensures that the plans, claims and justifications officially submitted to the paying agency fit with the digital information the paying agency obtains from other sources. This helps improve the quality of these products, and therefore it costs less time at the paying agency to make a decision.

How was the system built?

The Dutch government provided EUR 10 million over 4 years for the collectives to develop the SCAN-ICT system. Case study participants estimated the ongoing annual costs of the system to be around EUR 1-2 million.

The system was built by a “Building Team”, comprising information communication technology (ICT) suppliers, the Netherlands Enterprise Agency, Dutch Provinces and BoerenNatuur. Team members worked together in an open, transparent and cooperative approach. The Building Team organises user groups and regularly consults them on their experiences using the system, collects suggestions on improvement and tests new proposals.

What does the SCAN-ICT system do?

The system is composed of three components described in turn below:

- **SCAN Office** provides for administration of contracts with farmer participants. It contains relevant farmer data (e.g. contact details), digital contracts, payment specifications for each participant, email correspondence between the Collective and the farmer participants. The SCAN Office system is a pre-existing tool obtained via a licencing agreement and was customised to some extent for the collectives’ specific requirements.

- **SCAN GIS** is a geographic information systems (GIS) environment used to register the management units (e.g. land parcels) for each different participant and link these to management activities (termed “management packages”). It was custom-built on the basis of a pre-existing tool. Data in SCAN GIS is exchanged regularly with the Paying Agency to ensure consistency between SCAN GIS and the Dutch LPIS. This component provides high resolution data and information in a range of GIS layers, such as parcel information, the kind of management a farmer and a collective agreed upon, and the specific requirements for such a management.

- **SCAN Financial** is used for financial administration and payments to farmers. It was developed separately in part because the SCAN Office system does not have a financial component, and also to ensure maximum security for financial payments.

As of June 2018, employees of a collective have their own SCAN-ICT account and only have access to the data of their collectives’ participants. Participants themselves currently do not have access, but this functionality is envisaged.

The SCAN-ICT system operates separately to and duplicates information gathered by the Paying Agency (Netherlands Enterprise Agency, NEA) within the Integrated Administration and Control System (IACS) which is relevant for the contract of the collectives. (Most important is the parcel information in the LPIS; specific information on farmers is not duplicated.) Data in SCAN GIS is exchanged and reconciled with the Paying
Agency on a regular basis to ensure consistency between the two systems. At this stage, NEA does not allow direct access to its system.

While this separation entails some duplication of data, it has the following benefits, which case study participants considered far outweigh the costs of duplication:

- The collectives use the SCAN-ICT system to collect and store more information than the Paying Agency needs to view. In particular, the SCAN-ICT system records data relevant to items in individual contracts with farmers (e.g. on-farm agri-environmental practices) which are not required by EU legislation.
- Information available to the Paying Agency would be used in EU-level controls conducted by the Paying Agency. For example, as the contract and amount of payment to a farmer by a collective is a private law agreement, this information is not submitted to the paying agency. This makes it possible for a collective to pay more to a certain farmer for a certain activity than the maximum agreed upon in the Dutch Rural Development Programme.

The protocol for information exchange between the NEA and the SCAN system is based on web services and standard messages. The exchange of reference information such as the LPIS reference parcels (AAN – Agricultural Area Netherland) and the farmers’ fields (from farmers’ CAP application) is based on the Dutch standard message system, the EDI-CROP message, which has been incorporated into the UN/CEFACT e-CROP message standard\(^{18}\). For the SCAN information exchange, extensions have been developed by SCAN and NEA.

This EDI-CROP messaging protocol is widely used in the Dutch agriculture community, for all kind of purposes, for example in farm management systems, shared data hubs such as JoinedData, and Akkerweb, and by the agriculture co-operations and service providers and software developers.

Thus, the information exchange between SCAN and NEA is fully aligned with other information exchanges in the Dutch agriculture community and is based on national (AgroConnect) and international standards (UN/CEFACT). Some of the software developers participating in the SCAN GIS system are also involved in app development for Dutch farmers. In many of these apps, sharing and using geo data from and with the NEA parcel registration system is an important functionality.

The system also includes “Quality Indicators”, which are constraints on data entry in the system to help prevent errors and to cross-check different elements to ensure consistency and ensure that management plans for individual participants (farmers, landholders, etc.) are “fit for purpose” (e.g. that practices are suitable for the land type on which they are to be applied; that they fit with regional or landscape level objectives, etc.). The addition of Quality Indicators is useful to demonstrate that the system is robust, and to help collective employees who administer the system to automate checks and reduce the risk of errors.

Further, interoperability protocols were developed to enable the SCAN-ICT system to interface with the Netherlands LPIS. This allows for automatic reconciliation between the two systems, minimising the costs of duplication and the risk of the systems becoming “out-of-sync”.

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\(^{18}\) See [https://www.wur.nl/upload_mm/6/f/9/0e55dbbc-4874-4e6c-9399-cf6e01a1c27a_Presentatie%20Webinar%20FarmDigital%20Frans%20van%20Diepen.pdf](https://www.wur.nl/upload_mm/6/f/9/0e55dbbc-4874-4e6c-9399-cf6e01a1c27a_Presentatie%20Webinar%20FarmDigital%20Frans%20van%20Diepen.pdf), accessed September 2018.
Ongoing developments

*Mijnboerennatuur.nl—a digital communication platform for collectives and farmers*

*Mijnboerennatuur* is an online platform which will “digitalise” communications between collectives and their participants. It will allow farmers to log into a separate application to view their own data in real time as well as key documents such as contracts. Once this platform is fully operational farmers wishing to have changes made to their data will be able to notify their collective within the application (in addition to existing contacts methods such as telephone or email). The collective can then either decline this notification, or approve it and send it on to the Paying Agency. This feature will make two-way communication between collectives and farmers simpler.

*Schouwtool—a digital tool to manage inspections*

*Schouwtool* will allow collectives to manage their inspections through SCAN-ICT, both the planning process as well as administering the results of the on the spot checks, done by the collectives themselves. External inspectors can log into their agenda and see when and where to go to conduct inspections, as well as what needs to be inspected. They can also administer the results into the tool. This allows for the inspection system to become more cost-effective.

Lessons learned

Lesson 1: *The SCAN-ICT system and related digital platforms assist pre-existing collective governance institutions to “go further”.*

The Netherlands has a long history of collective governance mechanisms in agriculture (Jongeneel and Pollman, 2014 [15]). However, while previously agri-environmental collectives did help farmers to co-ordinate their conservation efforts, in practice most contracts under the CAP were still with individual farmers. The SCAN-ICT system and related digital platforms enable a landscape approach by providing a cost-effective way to track and aggregate information on individual conservation contracts and actual efforts on a landscape scale, and present information in an accessible and easy-to-understand format (e.g. by visualising data in GIS map layers) so that all stakeholders can be “on the same page”.

Also, historical individual contracts (and even early collective contracts) did not provide flexibility; conservation actions were fixed for the duration of the contract (typically 5-6 years). In contrast, the new model allows for a collective to adjust its management plans up until 14 days before a planned activity is to take place. According to Jongeneel and Pollman (2014, p. 6[15]), it is only due to the “especially developed ICT structure” of the collectives that this flexibility is made feasible.

Lesson 2: *The SCAN-ICT system can pave the way for result-oriented agri-environmental policies.*

Many researchers have pointed out that moving towards policies which are more result-oriented (as opposed to action- or practice-oriented) has the potential to deliver gains in policy efficiency and effectiveness (Burton and Schwarz, 2013 [16]).

The high level of spatial resolution of the SCAN-GIS system and the ability to add information on different aspects via different GIS layers (e.g. information on different types of environmental outcomes, such as impacts on biodiversity and water quality) could pave the way for implementing such results-oriented policies. However, effective results-oriented policies rely on having adequate information (either monitored or modelled) on
results, and (depending on scheme design) the ability to link results at different scales (e.g. linking on-farm or edge-of-field results with broader outcomes such as impacts on ambient water quality). The basic principles of the collective approach are adopted in the CAP 2020-2027. However, case study participants considered that the SCAN-ICT will probably need to be adjusted depending on the focus of different new schemes.

**Lesson 3: The SCAN-ICT system facilitates confidence and trust between actors and across different administrative levels.**

As described above, the Dutch collective model uses the institution of the collective and the system of collective contracts and individual subcontracts to re-distribute roles and responsibilities, and to provide additional flexibility to the administration of agricultural payments and agri-environmental schemes. This system of contracts, payments and (potential) sanctions entails the well-known problems of information asymmetries, risk of hold-up, transaction costs and co-ordination failure.

The SCAN-ICT contributes to solving these challenges firstly by providing a single system that delivers information to different parties according to their different needs. Note that this system is *not* based on principles of Open Data *per se*; rather, the system delivers what can be considered “targeted transparency”: for example, Paying Agencies are not able to access the system directly, and while farmers will be able to view their own data, they cannot view that of other individuals. This targeted transparency builds up the position of trust and authority of the collectives, in that the collective is the institution in the system who has the *most* information.

Second, the inclusion of Quality Indicators and LPIS interoperability builds confidence and trust by reducing the risk of errors or the risk of the SCAN-ICT system becoming “out of sync” with the LPIS. Again, this contributes to building the reputation of the collectives as well-managed, professional organisations.

Third, the system allows for real-time accounting for myriad of individual actions (as well as changes to planned actions), which, as noted in Lesson 1, is crucial for implementing the desired flexible and landscape-based approach of the Dutch model. Real-time tracking and aggregation allows for clear communication between different administrative levels, and across the many participating farmers, again increasing confidence and trust in the collectives as an institution, and in the system as a whole.
Lesson 4: The “Building Team” was essential to implementing well-functioning digital tools that met administrative and user requirements.

ICT suppliers, the NEA, provinces and BoerenNatuur work together in a “building team” to collaboratively develop, implement and refine the SCAN-ICT systems. The building team also convenes “user groups”, in which users are asked to share their experiences using the SCAN_ICT systems with the building team, as well as their suggestions for improvements and opinions on new proposals. The building team works to continuously improve the systems.

Case study participants identified that one of the advantages of the building team was that it was quite small and physically situated nearby the builders of the paying agency, which made communication between the two groups more effective. Furthermore, the chairman of the collective in which area the builders lived, was one of the main builders and testers.

Lesson 5: The staged approach—first building SCAN-ICT and then the Mijnboerennatuur.nl and Schouwtool platforms—has worked well in the Dutch context.

Case study participants identified that a staged approach to implementing the SCAN-ICT and related tools worked well in the Dutch context. In particular, this approach:

- Allowed the building team to be kept relatively small, which contributed to the success of the building team’s collaborative approach
- Allowed building new tools or refinements at a later stage to improve the existing system (rather than building separate tools at the same time)
- Made specific projects or milestones easier to achieve; participants felt that if all elements were pursued at the same time, the risk of not finishing some or all elements is much larger.

Lesson 6: A mixture of old and new tools was the most cost-effective approach in the Dutch context.

The SCAN-ICT system is a mixture of pre-existing tools (SCAN Office) and new, custom-built tools (SCAN Financial). At the start of the initiative, different options were evaluated, and the mixed approach was selected. Case study participants commented that the experience of using both pre-existing and custom-built tools shows that:

- Generally a new system is more prone to faults than customising a pre-existing system.
- Using pre-existing systems allows system users to learn from system providers.
- Working with several different providers (i.e. for the different SCAN components) is not always easy but has the benefit that providers have deep, specific product knowledge.

It is not expected that the same conditions will necessarily prevail in other contexts. Therefore, the recommendation is that other countries considering implementing a similar approach should:

- Form a clear view about the technological requirements, including whether these will appropriately reflect (existing or desired) administrative arrangements;
- Canvass a variety of options (adapting pre-existing tools, new custom built-tools, or a hybrid of both) at the outset. This could include planning for a staged introduction of new digital tools if this is considered desirable (see also Lesson 5).
• Plan from the beginning for the tools to be able to be adapted to new policy contexts (e.g. the introduction of more result-oriented or targeted policies).
• Involve stakeholders in the development of new policy-options and tools.

References


Case study 3: Gully erosion monitoring in Australia’s Great Barrier Reef catchments

Case study objective

The case study objective is to give a practical example of how remote sensing technologies and data or analytical products generated using these technologies can improve the effectiveness and efficiency of gully erosion and sediment control programmes.

Context: tackling water quality impacts of sediment transport in Great Barrier Reef catchments

Australia’s Great Barrier Reef (GBR) is an international icon of great value and is listed as a World Heritage Area. However, the health of the reef has been in decline for many years now, due to a variety of environmental pressures. One important pressure is the transport of nutrients (nitrogen and phosphorous) and sediment downstream from GBR catchments into the GBR lagoon (Jacobs, 2014[17]).

Recent studies have identified that “gully erosion is a dominant contributor of sediment, particularly in the Burdekin and Fitzroy catchments” of the GBR. In addition, gully erosion is also a problem for livestock graziers, as it degrades the condition of the land, reducing productivity (Tindall, 2014[18]).

In recognition of the significant negative impacts caused by gullies, the Reef Trust Gully Erosion Control Programme was established in 2016, through which the Australian Government allocated AUD 7.5 million (exclusive of GST) towards “projects across the four targeted natural resource management regions in Queensland, to fund community groups and organisations to work with private landholders to remediate high risk gullied areas”.19 Also, in order to be able to track how erosion and sediment management initiatives are impacting transport of sediment to the GBR, the Paddock to Reef Integrated Modelling, Monitoring and Reporting Program (P2R) was established, with funding jointly supplied by the Australian and Queensland Governments.20 As explained by Darr and Pringle (2017, p. 1921[19]), “the catchment loads modelling component of this programme estimates average annual loads of key pollutants for catchments draining to the GBR, and assesses changes against baseline levels due to improvements in land management practices. As well as reporting progress against water quality targets, the models are used to guide investment priorities.”


Use of digital technologies to improve gully erosion mapping

The problems

While substantial resources have been allocated to gully erosion prevention and control initiatives (as described above), these funds are finite and must be used as cost-effectively as possible. Information on where gullies are located, and how they (and sediment transport downstream) are changing over time, is fundamental to being able to target prevention and control efforts to where they will be most cost-effective. The modelling component of the P2R initiative (used to track overall progress towards sediment-related goals for the GBR) similarly relies on having accurate information on a range of complex physical processes, including sediment erosion and transport. However, until recently, this information has been scarce and costly to obtain. According to Tindall (2014[18]):

There has been limited work undertaken to comprehensively map gully locations, and to quantify and monitor gully erosion processes in GBR catchments at scales or resolutions appropriate for land management decision-making. Where mapping studies have been conducted, the information has been of limited use due to low accuracy, scale limitations or the maps being of limited geographic extent.

Darr & Pringle (2017, p. 1920[19]) similarly note that:

“Previous attempts to map gully density within the GBR catchments have been conducted by either intensively mapping gully erosion for relatively small isolated areas where gullies are prominent, or by defining the extent of gully erosion at a number of sample sites and then using predictive models to estimate gully density across much larger areas. Due to scale limitations, low accuracy or limited geographic extent, both these approaches have produced maps with limited usefulness for modelling water quality improvements. Consequently there is a need for a methodology that can improve the confidence in gully density maps over broad areas, in a timely fashion, and at a spatial scale that enables the modelling of water quality improvements due to on-ground investments, and allows prioritising of remediation strategies in the GBR.”

These problems are not unique to sediment erosion in GBR catchments. They relate to fundamental challenges caused by information gaps, and the high costs involved in gathering the required information using traditional data sources and collection methods, particularly over very large spatial scales (see conceptual framework in Figure 2.1 in main report).

Digital solutions

Advances in remote sensing technologies offer the opportunity to improve information on gully erosion, at lower cost than existing methods. While remote sensing—particularly aerial images—has long been used to supplement in-field measurement, there is a range of newer remote sensing technologies that, until recently, had not been deployed to map gully erosion, in GBR catchments or elsewhere. The Queensland and Australian governments have funded several projects that aim to assess the suitability of a range of remote sensing technologies in this context. Key projects are:

- **Gully mapping and drivers in the grazing lands of the Burdekin catchment** (Project RP66G)
Funded by the Department of Environment and Heritage Protection's Reef Water Quality (RWQ) Science Program and led by the Queensland Department of Science, Information Technology, Innovation and the Arts’ (now Department of Environment and Science) Remote Sensing Centre (RSC), this project mapped and quantified gully extent and rates of change at a range of scales in the Burdekin catchment using airborne and terrestrial LiDAR data.

Airborne LiDAR survey (ALS) typically ranges in cost from around AUD 60-100 per sq. km, depending on providers, sensor and flying specifications, area acquired and post-processing requirements. This makes airborne LiDAR a relatively expensive option, however, with appropriate industry standards and effective survey control both within and between multi-date acquisitions, and appropriate sampling design, it remains an effective and accurate approach for detailed characterisation of gully morphology and relative changes over time. The RP66G project captured a number of locations in a sampling strategy aimed a multi-date, detailed gully change monitoring approach. Some issues were encountered in the project with data quality and post-processing, highlighting the need for the establishment of industry standards and potentially the development of guidelines for the capture of ALS specifically intended for gully change monitoring. The RSC has addressed some of these issues by developing an end-to-end ALS processing system which standardises ALS data acquired from multiple providers and a range of specifications, improving the ability to make change estimates over time. However, deriving gully extent information from ALS remains a challenge and automated classification approaches should aim to quantify uncertainty in any estimates of gully change, particularly when evaluating the effectiveness of remediation efforts. Importantly, the RP66G project progressed research into quantification of uncertainty in change estimates derived from airborne and ground-based or terrestrial LiDAR (TLS). The work has culminated in a recent publication by Goodwin et al. (2017) which compared survey control data, ground based LiDAR and airborne LiDAR to quantify and report uncertainty in change estimates derived from these technologies. The authors concluded that:

“ALS can detect large scale erosional changes with head cutting of gully branches migrating...” while “TLS captured smaller scale intra-annual erosional patterns largely undetectable by the ALS dataset…” and therefore “suggests TLS and ALS surveys are complementary technologies and when used together can provide a more detailed understanding of gully processes at different temporal and spatial scales, provided the inherent errors are taken into account”.

This project “[p]rovide[d] spatially-comprehensive mapping and monitoring of gully erosion in the Burdekin catchment to improve knowledge of where gullies occur and to attempt to better understand the processes and drivers of gully erosion, particularly in the grazing lands of the catchment” (Tindall, 2014, p. i[18]). The improved mapping, produced at 5km and 1km resolutions, was achieved by “visual [i.e. manual] observation of satellite and aerial imagery and predictive modelling”. A mapping guideline (Darr, Tindall and

21 LiDAR (Light Detection and Ranging) is an active remote sensing sampling tool which uses the length of time a laser beam takes to return to the sensor to calculate distance. It is a key technology to obtain data used to construct Digital Elevation Models (DEMs) and derive metrics of vegetation height, structure and cover. For a simple explanation, see https://gisgeography.com/lidar-light-detection-and-ranging/, accessed August 2018.

22 “The 5km resolution mapping combined high resolution mapping, a predictive model of gully presence and visual observations of gully prevalence across the entire catchment. Gully presence
Ross, 2014[21]) was also developed to support ongoing application of this approach in other parts of the GBR grazing lands and potentially other locations facing similar challenges. The project also published a number of data outputs (e.g. gully presence maps and digital elevation models) on departmental websites under a Creative Commons licence. These outputs serve multiple needs, including:

- providing improved information for targeting erosion prevention and remediation efforts;
- supporting grazing extension programmes aimed at improving grazing land management to improve sustainability of the grazing industry in GBR catchments;
- helping to improve water quality models (e.g. the P2R models) which are used to assess progress in achieving environmental objectives for the GBR.

Building on the work of the RP66G project, Darr and Pringle (2017[19]) applied the project’s techniques to build grid-based presence maps24 (GBPM) of gully erosion at 1 ha spatial resolution. They then linked these maps with “a range of landscape attributes such as slope, distance-to-stream and soil erodibility to produce a predictive model that has the ability to generate gully density maps for all GBR catchments” (p. 1920[19]).

- **Monitoring Gullying Processes in the Great Barrier Reef Catchments (Photogrammetry project)**

  Funded by the Australian Department of Agriculture and Water Resources and led by CSIRO, this project assessed the suitability of “digital photogrammetry25 applied to aerial images routinely collected by state land survey agencies [for addressing] the challenges posed by gully erosion and sedimentation” (Poulton et al., forthcoming, p. i[22]). The outputs of the project are:

  - An assessment of the suitability of digital aerial photogrammetry for mapping and monitoring of gully erosion processes in the GBR Natural Resource Management (NRM) regions.
  - High resolution ortho-rectified images, digital surface models (DSMs) and associated ground elevation model (GEM) and water flow maps to help

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24 Grid-based presence mapping is a technique which a process which “allows an operator to map the presence or absence of gully erosion within a grid cell, using custom-built geographic information system (GIS) tools, aerial photography and uniform grids.” (Darr and Pringle, 2017, p. 1920[19])

25 As explained by Poulton et al. (forthcoming, p. 16[22]): “Digital photogrammetry is the science of making, among other things, geometric measurements from images. Digital aerial photogrammetry attempts to reconstruct three-dimensional surfaces from overlapped (stereo) aerial images. The process of digital aerial photogrammetry is as follows: acquire aerial image data, triangulate images, generate three-dimensional surface models and orthoimages. The main processing tasks are performed by means of a digital photogrammetric system. Additional processing steps are applied to further analyse the outcomes and create specific derivative products.”
landholders, NRM groups and researchers identify locations of high erosion risk requiring evaluation, monitoring or intervention.

- Documentation of specifications required for future air photo capture to enable DSM generation at appropriate resolutions for gully mapping and monitoring at other locations across Australia.

Poulton et al. (forthcoming, p. ii[22]) provide an overview of the technical process to produce the DSM and GEM:

[H]igh performance computing and digital photogrammetry was employed to generate radiometrically calibrated image mosaics and to create a digital surface model (DSM) capturing landscape and watershed features including gullies. Aerial data was acquired at a native image resolution of 0.1 m for two case study regions covering 520 km² in the Upper Burdekin and Bowen-Bogie catchments in Queensland. Surface infrastructure and vegetation was removed from the DSM using automated computer algorithms to generate a ground elevation model (GEM). This GEM is applied to the generation of a flow path prediction model that simulates water flow across a landscape surface. These GEMs were compared with high resolution (± 2.5 cm accuracy in elevation) survey points distributed within both study areas and correlated with aerial laser scanning (ALS) and terrestrial laser scanning (TLS) surveys within the confines of selected gully sites. Analysis of the GEM for the surveyed sites found that 48% of the photogrammetric elevations in the Upper Burdekin site, achieved < 0.1 m vertical error in detecting the ground surface, with 81% of locations within 0.3 m of the surveyed measurements. Both study areas exhibited 14% of sites with > 0.5 m vertical error, a product of filtering and interpolation error due to shadowing by standing vegetation.

This description makes clear that a number of different digital technologies are combined to produce the final project outputs, including:

- Digital photography to acquire aerial images
- High performance computing and digital photogrammetry to process aerial images to produce elevation measurements
- Algorithms to remove surface infrastructure and vegetation, as described above, and also to interpolate ground surfaces for areas below dense tree canopy
- Digital flow path modelling.

This study concluded that “[t]he technology is cost effective and capable of capturing high resolution (sub metre) data for large regional areas with acquisition and processing at $35-70 per km² for resolutions of 0.5-0.2 m and is compared with current acquisition of [aerial laser scanning] ALS at $50-100 per km²” (Poulton et al., forthcoming, p. ii[22]). The cost structure displays economies of scale, as fixed costs of deploying an aircraft to the region of interest account for a large portion of the cost (Poulton et al., forthcoming, p. 39[22]). Further, since aerial photographs are routinely taken by government agencies for a range of purposes, the cost of acquiring imagery for a specific purpose (in this case, gully erosion mapping) could be at least partially shared across different users. Finally, use of satellite data, the costs of which are declining rapidly, is promising for the future.

However, photogrammetry does have certain drawbacks, including that the cost of acquiring imagery is weather-dependent (as photographs cannot be taken through clouds), and that it is not an accurate method in areas of higher vegetation cover and is still unproven in detailed gullied environments. Further, case study participants noted that the ability to take advantage of routine acquisition of data by government depends on data collection
protocols providing sufficiently high quality data, currently, government acquisitions do not capture the data with appropriate specifications for deriving accurate high-resolution DEMs and therefore are not readily applicable. Additionally, many government captures do not provide overlapping photography at all due to new sensors and cost reductions (pers. comm. Dan Tindall, Queensland Department of Environment and Science & Joint Remote Sensing Research Program Remote Sensing Centre, August 2018).

Lessons learned for the application of remote sensing and predictive modelling technologies for erosion mapping in agricultural lands

**Lesson 1: Use of advanced remote sensing techniques to map erosion processes over large spatial scales is technically feasible and yields improved results but is still relatively costly and challenging to undertake. Large knowledge gaps remain, and a combination of tools may be necessary to enable cost-effective mapping techniques and erosion management strategies.**

In the synthesis report for the RP66G project, Tindall (2014, p. 78[23]) concluded:

> Gully mapping across large areas using remotely sensed imagery is challenging. It relies on having a consistent, repeatable and mappable definition of gullies which can be applied at multiple scales and across multiple image capture platforms. Simple, pragmatic and efficient methods are required to ensure consistency in the application of any mapping approach. Outputs must balance available resources for mapping against end-user requirements. A key outcome of this project has been the development of a guideline for catchment-scale gully mapping in Queensland. The guideline provides clear definition, guiding principles and efficient methods for manual and semi-automated mapping of gullies.

Similarly, for the photogrammetry project, Poulton et al. (forthcoming, pp. 41-42[22]) concluded that:

> While aerial photogrammetry cannot provide the level of surface detail of ground based RTK [real time kinetic] GPS, it is currently an economical method for delivering a high resolution GEM and associated surface flow path prediction model at a regional scale when compared with alternative technologies. DOMs [digital ortho mosaics] and RGB images and in particular the flow path model overlay are powerful communication tools for use in discussion with researchers, agricultural and natural resource managers and wider community groups. Integrating photogrammetry techniques for generating a DSM and GEM with routine aerial acquisition by state and commercial agencies will provide additional layers of contextual information to existing aerial photographic images. Application of aerial photogrammetry in deriving a ground elevation model for evaluating changes at a coarser resolution and for larger regional catchments will help inform landscape managers and enable better targeting of resources for prevention or remediation in areas subject to erosion processes.

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26 Poulton et al. (forthcoming, p. 10[22]) note that “[p]rovided sufficient digital data for panchromatic – nadir (forward and backward view) and 4-band multispectral nadir (backward views) are retained and the collection method follows standardised and rigorous protocols detailed in Section 2.1.3 and Appendix 3 [of this paper], future aerial acquisition may provide a source of low cost data needed to produce and periodically update fine scale digital surface models (DSMs) aiding erosion risk management.”
Nevertheless, a number of challenges remain. The key challenge for all aerial techniques studied is how to improve interpretation of ground surfaces, especially in areas with high vegetative cover. Therefore, a mix-methods approach appears to be the most cost-effective: use of photogrammetry techniques for large areas with low vegetation cover, supplemented by (more expensive) ALS or TLS techniques where detailed gully profiles are required or in areas where dense vegetative cover predominates.

Part of the challenge in tracking changes in erosion levels over time is that historical data (e.g. photographs) may be difficult to locate and are often of poor quality. This highlights that the usefulness of initiatives to track erosion (and other physical processes which occur over similar timeframes) is dependent on having a sufficiently high quality time series data. Therefore, even those initiatives which are now acquiring high quality data may take some time to yield precise results.

As noted above, while the RP66G project made use of new technology in the form of LiDAR data and new predictive modelling, it still relied on visual (i.e. manual) inspection of satellite and aerial photography to identify and classify gullies. The project did investigate the possibility of automating processing of LiDAR data to accurately map and quantify gully extent and volume; however, Tindall (2014, p. 73) commented that the automated method used to classify gully extents for individual dates was not robust enough to reliably compare and map change in gully extents between dates and over time.” The authors noted (p.81) that machine learning approaches suggested by others may warrant further inquiry, but that this was beyond the scope of the current project.

Darr and Pringle reported that their project (based on the RP66G methodology), as of 2017, used approximately 1.4 full-time staff equivalents to map and quality check on average 4200 km² per month, achieving 87% accuracy when checked against field observations. At this rate, the authors estimated approximately five years would be required to fully map the remaining 300,000 km² of the GBR catchments. Thus, while more efficient than other manual techniques, this is “not a quick process” for basins as large as those in the GBR catchment (Darr and Pringle, 2017, p. 1925). These authors also identified that a further step would be to automate the mapping process using machine learning techniques, but, as with the RP66G project, this has yet to occur.

The RP66G project and photogrammetry project authors also identified that a range of other emerging remote sensing technologies could be useful to improve mapping efforts, and recommended these be explored in further research.

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27 Tindall (2014, p. 79) observe that “[m]apping changes in gully extents using historical imagery is challenging and resource intensive, particularly for large areas. Locating historical imagery for a particular location requires extensive investigation of air photo archives to find suitable imagery that can be geo-located accurately to be able to reliably compare change over time. Identifying gullies in older imagery, and also in some new imagery, can be extremely difficult, resulting in a large degree of subjectivity in mapping outputs.”

28 “New technologies are emerging such as Unmanned Aerial Vehicles (UAVs) and space-borne stereo imagery. DAFF has previously demonstrated the application of UAVs for capturing imagery and generating digital surface models over a gully remediation trial on Spyglass Research Station in the Burdekin. Outputs still require testing and validation but the results did show some promise. It is suggested that further investigation of UAV technology for mapping and monitoring gullied areas be considered. With regards to space-borne stereo imagery, RSC has an agreement with the Chinese Satellite Applications Centre for Surveying and Mapping (SASMAC) who operate the ZY-3...
Further, knowledge of where and when gullies occur is not the only information gap needing to be filled. Other crucial areas of inquiry are to understand the “fate and timing of sediment delivered from gullies” and to develop “the most appropriate technologies and approaches for managing and monitoring gullied areas” (Tindall, 2014[18]). The RP66G project concluded that:

_Emerging technologies such as ground-based laser scanning, imagery and LiDAR capture from Unmanned Aerial Vehicles (UAVs), sediment tracing and digital soils mapping all present opportunities to help improve our understanding of gully processes to enable effective management strategies for improving land condition and water quality in the grazing lands of the GBR. (Tindall, 2014[18])_

Thus, it is important to place the use of technology for a specific purpose (monitoring gullies) in the broader context of the overall policy objective (reducing negative impacts of erosion on the GBR), and ensure that there is a balanced approach to investigating different questions.

**Lesson 2: Improved understanding of physical processes must be balanced by economic considerations.**

The techniques described here have the ability to significantly reduce information gaps about where and when gully erosion is occurring. This knowledge is fundamental to efforts to address the negative impacts of erosion, both for the Great Barrier Reef and more broadly for livestock producers and rural communities who rely on the productivity of land at risk from gullying.

However, there is still “very limited information about the cost-benefit of gully prevention and remediation approaches” (Tindall, 2014, p. 14[18]). A holistic assessment of costs should include both the actual implementation costs of different approaches as well as the transactions costs of programmes which aim to increase uptake of management actions by land managers. Targeting remediation and prevention efforts based only on the information provided by gully mapping ignores spatial differences in management costs and transactions costs, which may be substantial.29 Information on both the benefits and costs of alternative erosion management activities is needed to ensure efforts are targeted cost-effectively. Tindall et al. (2014, p. 82[23]) recommend that “where possible, science and monitoring efforts be combined with on-ground efforts and economic modelling to improve knowledge of where and when to expend resources for gully management.”

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satellite. This satellite has high resolution stereo-imagery capable of producing 4m digital surface models.” (Tindall, 2014, p. 81[23]) See also section 5.1 “Future Opportunities” in Poulton et al. (2018, pp.43-44).

29 For example, (Wilkinson et al., 2015[71]) reports that the direct management cost (i.e. excluding any reports that the direct management cost (i.e. excluding any programme-related transactions costs) of the recommended combination of management techniques for GBR grazing lands (consisting of fencing around gullies, gully channel revegetation with native perennial tussock grasses, use of check dams or other sediment traps to prevent gullying, and managing grazing pressure to avoid vegetation clearing and restore perennial pastures) varies between AUD 4 500 and AUD 9 000 per km of gully. Variation in cost-effectiveness per tonne of reduction in mean-annual sediment load is largely dependent on the efficiency of fencing.
Work to evaluate the relative costs of different erosion management activities and programme-related transactions costs is ongoing. However, in a recent audit of measures taken to address issues affecting the GBR, the Queensland Audit Office found that, as of June 2018, the Queensland government “cannot measure the degree of practice change or assess the value achieved from its investment of public funds. The Office of the Great Barrier Reef is currently negotiating with industry groups to gain access to the data the departments need and should have access to” (Queensland Audit Office, 2018, p. 9[24]).

Lesson 3: Benefits and challenges of collaboration across organisations and across projects.

Both the RP66G and photogrammetry projects were highly collaborative and brought together researchers from a range of state and national government agencies, including CSIRO, Department of Agriculture and Water Resources, Queensland Department of Department of Science, Information Technology, Queensland Department of Natural Resources and Mines, the National Environmental Science Programme and Innovation and North Queensland Dry Tropics Regional NRM group. These projects are part of a broader portfolio of research activities that are continuing to contribute to identifying, defining, characterising, measuring and modelling change in gully systems in key Great Barrier Reef catchments. This research utilises a range of data collection methodologies and techniques (e.g. airborne and terrestrial laser scanners and ground based and aerial photogrammetry) each with unique strengths, weaknesses and costs associated with collecting and data processing.

Increasing costs associated with this type of research and the rapid on-going technological development in the collection of ground based, remoted sensed and large spatial data requires adaptation, innovation and successful collaboration of the research community. For the photogrammetry project, having access to a wider research network currently undertaking project activities within the GBR region enabled transfer of localised knowledge which helped identify suitable case study areas. Selected sites were aligned with existing ground measurements undertaken by research collaborators in the region. In this case, collaboration facilitated opportunities to access data sources from past and current projects (e.g. aerial and ground based LiDAR, gully location mapping, aerial and ground photography, satellite imagery) as well as experience gained by those researcher’s familiar with use of the different technologies. Collaborative exchange delivered cost savings in data collection for individual projects as well as useful calibration and validation data made available between different project groups. Spatial data collected and generated by the photogrammetry project is to be made available to ongoing projects within the GBR study region.

While there was a willingness for collaboration between projects, in reality researchers share their time between a number of competing activities. Opportunities for the wider research community, particularly different organisations, to meet face to face regularly are infrequent. Within a twelve-month period one successful workshop was held which brought together a larger group of researchers with wide-ranging experience in technologies and methodologies for quantifying gully systems. Focused discussion and a sharing of experience targets not only a knowledge exchange between researchers but helps quantify

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information on the appropriate technology for a particular application and helps to inform the wider research and government agencies.

References


Case study 4: Earth Observation initiatives for administration of the European Union Common Agricultural Policy

Case study objective

The objective of this case study is to provide practical examples from the European context of how digital technologies can improve systems which pay farmers for producing ecosystem services.

Context: reforming the CAP’s administration

The European Union (EU) Common Agricultural Policy (CAP) is the overarching system of subsidies and payment programmes for agriculture and rural areas in the European Union. The CAP pursues a range of objectives, and accounts for over 40% of the EU’s annual budget.

Schmedtmann and Campagnolo (2015, p. 9326) provide an overview of the administrative mechanisms of the CAP:

To ensure that CAP funds are spent appropriately, Member State Authorities have to comply with legal management and control mechanisms...Each Member State is responsible for subsidy administration and control, which are carried out by a National Control and Paying Agency (NCPA).

In order to obtain area-based financial support [direct payments], farmers are required to submit an application to their NCPA early in the year, where they declare the precise location of all of their agricultural parcels, as well as the crop type. The National Agency is responsible for controlling at least 5% of those declarations and penalizing farmers who submit incorrect information by performing so-called On-The-Spot (OTS) checks. For area-based subsidies, an agricultural parcel must be controlled at two different levels: both the declared crop and area must be correct. The [European Commission] in turn controls the NCPAs. When discrepancies between the control result and the reality are found, a Member State is penalised and has to return to the EU part of the subsidies that were distributed to farmers.

The complex process of subsidy control requires computational tools: NCPAs rely on Integrated Administration and Control System (IACS), which includes a [Land Parcel Identification System] LPIS. The main functions of those spatial databases

31 In particular, the CAP aims to:

- “support farmers and improve agricultural productivity, so that consumers have a stable supply of affordable food
- ensure that European Union (EU) farmers can make a reasonable living
- help tackling climate change and the sustainable management of natural resources
- maintain rural areas and landscapes across the EU
- keep the rural economy alive promoting jobs in farming, agri-foods industries and associated sectors” (European Commission, n.d.,[72]).
are localization, identification and quantification of agricultural land via detailed geospatial data, in order to facilitate the distribution of CAP subsidies.

Following the 2013 CAP reform, EU farmers are able to apply for direct payments through the Basic Payments Scheme (BPS) (OECD, 2017[26]). These payments are intended to act as a safety net in the form of a basic income support. Cross compliance and Greening are two mechanisms (referring to specific obligations) that are linked to this payment to ensure more environmentally-friendly farming approaches and deliver continued food security and safety in Europe. The introduction of cross compliance and greening measures introduces additional complexity for programme administrators.

**Use of digital technologies to streamline CAP administration**

**The problems**

The CAP is fundamentally an eligibility-based system: while the conditions have changed over the years (particularly with the decoupling reforms in the mid-2000s), farmers must still meet certain criteria in order to receive payments. As in regulatory contexts more generally, the eligibility system introduces a potential **incentive misalignment** problem: while the administrator has incentive to discover whether the farmer meets the criteria, absent the threat of sanctions, a farmer would prefer to receive the payment without incurring costs needed to achieve eligibility for the payment. This creates incentives for farmers to preserve **information asymmetries** between themselves and the administrator (i.e. the farmer knows his or her own action but may have incentive to prevent the administrator from accessing that information). The reform of the CAP to include environmental greening and cross compliance requirements, which may be costly for farmers to meet, exacerbates this potential. Therefore, a system of monitoring, controls and sanctions is needed to ensure the effectiveness of the payment as an incentive mechanism for improving the sustainability of European agriculture.

As outlined above, there are three main administration and control tools used by the relevant competent public authorities (‘National Control and Paying Agencies’, NCPA): administrative checks of paperwork submitted by claimants (farmers), physical on-the-spot checks (OTSC) and Control with Remote Sensing (CwRS). Due to the high complexity and diversity of the obligations that need to be verified, each method has its limitations. As a result, existing administration and control regimes entail high **transaction costs** for public administrators as well as private transaction costs and administrative burden for farmers. For example, according to DG-AGRI (Borchmann, n.d.[27]), the cost of controls to Member States in 2015 was EUR 1 125 million, which equates to 5.2% of total public CAP expenditure.

The challenge for CAP administrators is therefore to minimise administrative transactions costs (both public and private) while maintaining effective standards of compliance. One crucial aspect of this is to reduce costs of obtaining information on farmers’ activities.

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32 And abstracting away from questions of additionality (i.e. whether farmers prefer to act in a way that is consistent with the policy even in the absence of the policy).

33 Here, we do not consider the overall cost-effectiveness of the CAP policy as a whole: such a consideration would require consideration of all relevant costs and benefits, not simply the
**Digital solutions: the RECAP initiative**

The use of digital technologies, particularly earth observation technologies and online digital platforms, offers the potential to provide improved monitoring of agricultural activities at lower cost than existing administration and control methods. While there are numerous initiatives research and testing of digital solutions aimed at reducing the costs of administrating the CAP while increasing information on farmers’ activities, this case study centres on one initiative from the European context: the RECAP—Personalised Public Services in Support for the implementation of the Common Agriculture Policy (CAP), an Horizon 2020 project funded under the ICT-enabled open government (H2020-INSO-2015-CNECT) call (Grant Agreement 693171), which aims to provide practical evidence on these potential benefits.

The initiative commenced in May 2016 with 30 months duration, involving 12 partners. The overall budget of the project is EUR 2.7 million (EUR 2.1 million requested EU contribution). It is based on the following interrelated objectives:

- To develop improved e-public services that enable a better implementation of the CAP and simplify administrative procedures, integrating open and user-generated data.
- To develop personalised public services that support farmers to better comply with CAP requirements.
- To increase the transparency of compliance monitoring procedures related to CAP.
- To enable the reuse of data (open and user-generated) by agricultural consultants and developers for delivering their own added value services for farmers.
- To pilot test the services in an operational environment with the participation of end users in five countries (Greece, Lithuania, Serbia, Spain and the United Kingdom).
- To assess the usability, effectiveness and impact of the proposed services in delivering the public administrations’ goals, and provide feedback into a set of recommendations for future use of these approaches to deliver more effective and applied public administration.

administrative costs of the monitoring and control system and the benefits of maintaining effective standards of compliance.

34 For example, the checks by monitoring approach developed by the Commission as an alternative to traditional checks on-the-spot, the Horizon 2020 SEN4CAP project. See also Box 2.

35 Draxis Environmental S.A. (Leader) (GRC), Instituto Navarro de Tecnologias e Infraestructuras Agroalimentarias SA (ESP), Payment and Control Agency for Guidance and Guarantee Community Aid, National Paying Agency of Lithuania (LTU), Viesoji Istaiga Lietuvos Zemes Ukio Konsultavimo Tarnyba (LTU), Strutt & Parker LLP (GBR), Inosens Doo Novi Sad (SRB), University of Reading (GBR), National Observatory of Athens (GRC), Iniciativas Innovadoras Sal (ESP), ETAM S.A. (GRC) and CREVIS SPRL (BEL).

36 This objective is related with the Software Development Kit (SDK). The SDK provides RECAP platform users (in particular agricultural consultants responsible for farmers registered in the platform) with tools that help them build new added-value services upon the RECAP platform. This functionality enables the use and reuse of open data. For example, agricultural consultants can retrieve data of the parcels declared, along with results derived by the RS component, for use in other applications.
RECAP is a commercial platform\(^{37}\) (cloud-based Software as a Service (SaaS)) that integrates satellite remote sensing and user-generated data into added value services for public authorities (administrators and inspectors), farmers and agricultural consultants, to improve the processes for implementing and monitoring the BPS. RECAP has three interrelated results indicators:

- Increasing the efficiency and transparency of public authorities’ procedures implementing and monitoring the CAP by enabling **effective and efficient remote monitoring of farmers’ obligations** (including automation of compliance checks for some requirements) through the use of open earth observation (EO), user-generated data (geotagged and timestamped photos) and purpose-built algorithms. The RECAP pilots aim to reduce administrator costs by at least 25% (see Table 2 below).
- Providing **personalised services to farmers for their better compliance with the CAP environmental standards** (Cross Compliance (CC) and Greening Measures). The RECAP pilots aim to reduce farmer administration costs related to BPS claims by at least 25% (see Table 2 below).
- **Stimulating the development of new added value services by agricultural consultants and developers who can create add-ons to the main platform and make use of the data collected.**

**RECAP digital components**

To achieve these deliverables, RECAP makes use of various digital tools or “components”, explained below (see also Figure 1).

\(^{37}\) The platform uses an open licence (GNU General Public License version 3; info available at: https://opensource.org/licenses/GPL-3.0). It is not intended to entail a cost for farmers. Certain costs relating to customisation or adaptations may be incurred by the paying agencies and other interested authorities. Operational costs are to be covered by the paying agencies.

The platform source code is available at: https://zenodo.org/record/1451796#.XOuNXYj7RPY
Remote Sensing component

The RECAP Remote Sensing (RS) component provides automated earth observation processing workflows to assist paying agency inspections of farmers' compliance with their CAP obligations. The methodology is founded on the accurate crop type classification via applying a machine learning algorithm to a time-series of combined Sentinel-2 imagery and relevant vegetation indices. The monitoring of compliance was algorithmically addressed for specific Cross-Compliance and Greening requirements\(^ {38} \) (see Box 1).

The practicality of the output RS information ranges from direct decision making (e.g. for crop diversification) to simple indicators of potential noncompliance (e.g. for minimising soil erosion), depending on the complexity of the individual CAP obligation. The RS component comprises three principal processing chains:

- crop type mapping (classification);
- runoff risk analysis; and

\(^ {38} \) These requirements are: Greening 1—Crop Diversification; Greening 2—Permanent Grassland; GAEC1—Buffer Strips; GAEC 4—Minimum Soil Cover; GAEC 5—Minimising Soil Erosion; SMR 1—Reducing water pollution in Nitrate Vulnerable Zones (VNZs) and GAEC 6—Maintaining the level of organic matter in soil.

identification of stubble burning.

The relevance of the developed RS solution to the CAP monitoring challenge is essentially based on the accuracy of the crop type classification. Accuracy was assessed by comparing classification based on satellite data obtained in two iterations\(^\text{39}\) against validated ground truth data obtained by pilot inspections in selected subsets of the dataset.\(^\text{40}\) As an example, the accuracy results obtained in the Spanish pilot are presented in Table 1. Validated results showed an overall crop type mapping accuracy in the range 80-90% for the identification of 9-13 different crop types, depending on the pilot, which explain more than 90% of the regional agricultural zone (Source: Pers. comm, case study participants, July 2018).

Table 1. Accuracy of RECAP Remote Sensing component crop classification, Spanish pilot

<table>
<thead>
<tr>
<th>Crop type</th>
<th>Producer's Accuracy</th>
<th>User's Accuracy</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Iteration 1</td>
<td>Iteration 2</td>
</tr>
<tr>
<td>Soft Wheat</td>
<td>92%</td>
<td>91%</td>
</tr>
<tr>
<td>Corn</td>
<td>91%</td>
<td>94%</td>
</tr>
<tr>
<td>Barley</td>
<td>91%</td>
<td>94%</td>
</tr>
<tr>
<td>Oats</td>
<td>77%</td>
<td>87%</td>
</tr>
<tr>
<td>Sunflower</td>
<td>84%</td>
<td>89%</td>
</tr>
<tr>
<td>Broad beans</td>
<td>72%</td>
<td>84%</td>
</tr>
<tr>
<td>Rapeseed</td>
<td>92%</td>
<td>91%</td>
</tr>
<tr>
<td>Vinification vineyard</td>
<td>79%</td>
<td>85%</td>
</tr>
<tr>
<td>Cherry trees</td>
<td>74%</td>
<td>74%</td>
</tr>
<tr>
<td>Shrubby grass of 5 or more years</td>
<td>64%</td>
<td>72%</td>
</tr>
</tbody>
</table>

1. Producer's Accuracy is the map accuracy from the point of view of the map maker (the producer). This is how often are real features on the ground correctly shown on the classified map or the probability that a certain land cover of an area on the ground is classified as such.
2. The User's Accuracy is the accuracy from the point of view of a map user, not the map maker. The User's accuracy essentially reveals how often the class on the map will actually be present on the ground. 
Source: (Draxis Environmental, 2019\(^\text{28}\)).

Overall, the crop classification algorithm was assessed to provide satisfactory results,: 75-85% accuracy, even for datasets that include satellite imagery only until mid-late June. This is very important, since paying agencies require accurate information at the time of the farmers’ applications, in order to better target their sampled on-the-spot inspections to parcels that constitute potential breaches of compliance.

Crop classification from the RS component was provided also with the crop type as declared by the farmers. This functionality is key for paying agencies, as (together with the ground-truthing accuracy), it allows probabilistic identification of potential non-compliance. The RECAP team developed a “traffic light system” to convey this

\(^{39}\) The first iteration used data from June 2018, right after the completion of farmers’ applications; and refers to the classification performed using satellite imagery until mid June 2018. The second iteration was in late August 2018; and refers to the classification performed incorporating additional imagery (new Sentinel-2 acquisitions) that was acquired throughout the summer.

\(^{40}\) For further details about the accuracy assessment, contact the case study participants.
probabilistic assessment in an intuitive way.\textsuperscript{41} Where the ground-truthing accuracy of the RS classification is high, but the RS classification disagreed with the declared classification, this indicates potential non-compliance (untruthful declaration). Towards the completion of the project, validated results were received for each of the three pilots as follows:

- **Spain**: Of 107 random parcels inspected, 105 were classified correctly.
- **Greece**: Inspectors visited only parcels that were selected by the smart sampling methodology; that is, parcels classified with high confidence to crop types other than the one declared, which are considered as potential breaches of compliance. It was shown that 76 out of 85 inspected parcels were indeed wrongly declared and correctly classified.
- **Lithuania**: The validated dataset acquired through the Lithuanian Paying Agency inspections revealed an actual overall accuracy of 76.2\% in late June and 80\% in late August out of 3 319 parcels inspected.

The crop type classification accuracy, and hence the usefulness of the RS component for CAP administrative decisions for which crop-type is relevant, depends on three parameters:

1. Percentage of truthful declarations
2. Cloud coverage
3. Parcel size

In one of the case studies—Navarra, Spain—where 90\% thematic accuracy was achieved, all these parameters were optimal. This means more than 97\% of truthful declarations, limited cloud coverage, and an average parcel size of 2 ha, which is considered sufficiently large for a Sentinel-2 based classification.

When a considerable percentage of declarations are not truthful, then similar crop types, both in spectral characteristics and phenology—e.g. wheat, barley, oats—might not be well discriminated. Hence, merging of such crop types into spectral coherent clusters (e.g. cereals) would be necessary for an adequately accurate result. Therefore, the thematic accuracy of the crop identification products depends on the type of information one is aiming for. For example, the usefulness of the clusters in assessing a crop rotation requirement depends on the degree to which farmers could implement a crop rotation within, as opposed to across, clusters.\textsuperscript{42}

Crop classification accuracy also depends on the size and shape of the parcel, with classifications for larger parcels and parcels with straighter borders tending to have higher accuracy than smaller parcels or parcels with more irregularly-shaped boundaries. The parcel area is important since accuracy depends on the number of image pixels that fall within the parcel boundaries. Sentinel-2’s 10 m pixel size equates to 50 image pixels in 0.5 ha of land. An analysis conducted, comparing the accuracy of classification in

\textsuperscript{41} “Green light” signifies an almost completely trustworthy decision, yellow a less reliable but still usable decision, and red and unreliable being decisions of low confidence (these should be used with caution).

\textsuperscript{42} The classification is performed for crop types (i.e. soft wheat, barley, oats), crop clusters/families (i.e. cereals, legumes, maize etc.) and crop season (i.e. summer, winter, permanent). All three levels of crop classification are provided to the PAs. According to the Greek Paying Agency, most of cross compliance rules are decided based on the crop cluster (family), with the exception of Greening requirements that require the lowest level of crop type differentiation.
conjunction with the parcels’ size, showed that having 50 pixels of information provides accurate results, whereas for smaller parcels the decision is both less confident and less accurate.

<table>
<thead>
<tr>
<th>Box 1. Evaluation of remote sensing (RS) and machine learning (ML) tools to classify crop types and monitor environmental requirements.</th>
</tr>
</thead>
</table>
| **RECAP** case study participants commented on the practicalities of using RS information and machine learning to successfully classify crop types and identify compliance with environmental requirements (e.g. GAEC, greening, etc.):
| “Different description of crop types would imply different spectral signatures for the crop classes and thereby different classification results. Additionally there are differences in the percentage of correctly declared cultivated crop types that accordingly affect the training of the machine learning algorithms. In Navarra, Spain declarations are almost completely correct and therefore results are excellent. In Greece, however, there is a significant percentage of falsely declared crop types that affects the classification accuracy. Nonetheless, the algorithm is indeed robust; in the sense that if 20% of declarations are wrongly stated this would roughly mean only 5% reduction in accuracy. Finally, in countries such as Lithuania, where cloud coverage is significant throughout the year algorithmic modifications are necessary. For example, it was found that a different machine learning algorithm performed best for the Lithuanian case.
| The main pillar of the agriculture monitoring scheme is the accurate crop type classification. The practicality of the classification is straightforward. However, **RECAP** attempted to specifically address the compliance of farmers to their actual **CAP** obligations (GAECs, SMRs, Greening). For some **CAP** obligations, such as Greening 1, crop classification is indeed all that is needed to decide on the compliance of the farmers. Now, for other obligations such SMR 1 (Reduce water pollution in nitrate vulnerable zones), the RS component of the **RECAP** platform provides a risk assessment on the soil loss and runoff to nearby watercourses, for each parcel. This is indeed a prerequisite for the farmers in order to comply with SMR 1, but the rule also extends to manure spreading obligations that cannot be addressed by remote sensing. Therefore, even though the remote sensing information provided with respect to SMR 1 is useful, it is not complete for compliance decision making.”
| Source: Case study participant, Dimitrios Petalios (CREVIS), June 2018. |

**Spatial component**

The spatial component depicts in digital maps (set in several layers) the information generated by the RS component as well as external spatial data, which are listed below. These maps enable users to visualise valuable information for an effective and efficient inspection process (Paying Agencies (Pas), inspectors) (Figure 2 below provides an example of how the PAs view the spatial component). The produced maps include:

- Time-series of Sentinel-2 true color composites and vegetation indices (viewing only);
- Natural habitat sites;
• Nitrate Vulnerable Zones;
• Botanical Heritage Sites;
• Watercourse maps;
• Slope map;
• Administrative boundaries and settlements;
• Land Use/ Land Cover Maps;
• Land Parcel Identification System (LPIS)
• RS-derived parcel specific thematic information (i.e. crop type mapping, polluted water runoff risk assessment, identification of stubble burning, soil erosion etc.). This is displayed in the form of a list, when interactively selecting the parcel of interest.

Figure 2: RECAP spatial component

Paying Agency view of Remote Sensing results in the region of interest, with the relevant parcel information.

Source: RECAP initiative case study participants.

The remote sensing results and the information provided by the Spatial component can be used by the PA as auxiliary information in their risk analysis process and identify the farmers that are more likely not to comply, so that they could proceed with more targeted inspections. Specifically, the PAs are able to draw a bounding box on the map, covering the area of interest, and for which they will receive the remote sensing analysis results. The crop classification information is also provided to the farmers through their own profile. Therefore if their parcel is classified to a different crop type than the one declared and with high confidence, then they could opt to change their declarations if they agree with the classification.

Business intelligence component

The Business intelligence component is aimed at the PA officers only. It is a data mining tool enabling public officers to analyse large datasets stored in RECAP platform. PAs will be able to make use of available data and create key performance indicators (i.e. CAP objectives) and relevant reports, enabling them to set targets and move towards a more result-oriented CAP support. Additionally, this tool allows PAs to extract valuable
information from such vast datasets and to uncover previously unknown patterns that may be relevant to current agricultural problems, thereby helping farmers and managing organizations to transform data into business decisions and ensure a better implementation of the CAP.

Workflow component

The workflow component is the core system of the platform, working as the link between the different parts of the system. Specifically, it brings together information that is processed by all components to the user in a way that is easy to understand. It functions as an orchestrator for the RECAP business logic, the communication with the data storage, the Application Programming Interface (API), the receipt of information from outside sources and the validation process. For example, it provides farmers, consultants and inspectors with checklists of Cross Compliance rules applicable to the farm, based on information from the BPS application submitted by the farmer; it guides farmers and inspectors with personalised information on the procedures to follow regarding the compliance procedure; generates notifications to farmers based on calendar of key dates; etc.

Software Development Kit

The Software Development Kit (SDK) allows agricultural consultants and developers to develop their own “added value” services in an open approach within the RECAP platform, and deliver improved advisory services to farmers. The SDK enhances the role of the platform, both by enabling consultants to develop their own services on top of the RECAP platform using design tools, libraries and communications with the database under an open approach; and also by supporting any technical integration with external systems.

The RECAP Digital Platform—Web and mobile application

The RECAP platform interconnects the different system components in order to deliver the deliverables earlier described. Being co-created and co-produced with its end-users, it covers five categories; the general system requirements, the Basic Payment Scheme (BPS) eligibility and applications, the farmer record keeping, the inspection process and the farmer education and information. The main features covered per category (table rows) and user group (table column) are presented in Table 2.
Table 2. Main features of the RECAP Platform (web application), by user group

<table>
<thead>
<tr>
<th>Feature</th>
<th>Farmers</th>
<th>Consultants</th>
<th>Paying Agencies</th>
<th>Inspectors</th>
</tr>
</thead>
<tbody>
<tr>
<td>Farm management</td>
<td>Farm management</td>
<td>Inspector assignment</td>
<td>Inspections management</td>
<td></td>
</tr>
<tr>
<td>Cross Compliance checklist</td>
<td>Cross Compliance checklist</td>
<td>Inspections management</td>
<td>Inspection scheduler</td>
<td></td>
</tr>
<tr>
<td>Greening Calculator</td>
<td>Greening Calculator</td>
<td>Communication between farmers and PAs</td>
<td>Farmer's data management</td>
<td></td>
</tr>
<tr>
<td>Farmer's log/ Farmer's Inspection</td>
<td>Farmer's log/ Farmer's Inspection</td>
<td>Document repository</td>
<td>Document repository</td>
<td></td>
</tr>
<tr>
<td>Communication between farmers and PAs or Inspectors</td>
<td>Communication between farmers and PAs/ Inspectors</td>
<td>Spatial component</td>
<td>Communication between farmers and Inspectors</td>
<td></td>
</tr>
<tr>
<td>Notifications/ Reminders</td>
<td>Notifications/ Reminders</td>
<td>Remote Sensing component</td>
<td>Spatial component</td>
<td></td>
</tr>
<tr>
<td>User roles</td>
<td>User roles</td>
<td>Business intelligence component</td>
<td>Spatial component</td>
<td></td>
</tr>
<tr>
<td>Spatial component</td>
<td>Spatial component</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Report problem</td>
<td>SDK component</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Source: RECAP initiative case study participants.
Note: SDK = Software Development Kit.

Apart from the web-based application platform, two mobile interfaces are developed; a smartphone-optimised interface dedicated to the farmers’ needs and another one focusing on the inspectors’ needs. The mobile application is mainly for the data collection on the farmer’s field either from the farmer or from the inspector during on-the-spot checks (to overcome connectivity challenges, the mobile application also has an offline mode – when operating in offline mode, data will be uploaded to the RECAP database once the mobile application is re-connected to internet).

On the RECAP platform, each farmer has their own personal account where they are able to store data, records, and documents that need to be obtained or retained. This can be presented to inspectors during an inspection. The RECAP platform allows the farmer to filter complex cross compliance rules and see only those relevant to their farm. There are also alerts for actions to be taken and potential non-conformities. These alerts provide farmers access to checklists and workflows through a mobile and web interface (the RECAP platform). The PA is responsible for updating and certifying the checklist(s).

Satellite imagery is available for all users of the platform. However, PAs are able to see the “big picture” (all parcels within the user-defined area of interest), while farmers and consultants see cropped imagery that includes only the farmers’ parcels.

The digital platform also enables PAs to increase the effectiveness of risk-based analysis for the selection of farms to be inspected through the help of the Remote Sensing component which uses a combination of open and user-generated data. The RECAP platform allows the PAs to select a farm for inspection and retrieve farm profile data and previous inspection results, which will be available both to the PAs and inspectors. Overall, RECAP delivers a platform to public administrations so that they carry out inspections more efficiently, more accurately and more quickly.

Implementing the RECAP pilot

The RECAP platform is currently being tested and validated in an operational environment in five countries—Greece, Lithuania, Serbia, Spain and the United Kingdom—with the active participation of public organisations, agricultural consultants, and farmers. The
platform is comprised of five different workflows (one for each country pilot), due to the differences between the pilots and the CAP rules interpretation. Based on this, the RECAP platform is developed as an integrated system, composed of core functionalities which are commonly shared across the pilots, with additional pilot-specific functionalities are built on top of these core functionalities.

Pilot implementation in Spain, Greece, and Lithuania is focusing on delivery of public services, with the participation of four public organisations (Paying Agencies and Agricultural Advisory Services) which are members of the project consortium (INTIA, OPEKEPE, NMA, and LAAS). In the United Kingdom, the pilot implementation focuses on the delivery of personalised services from agricultural consultants (partners STRUTT & PARKER).

The Serbian Pilot (INO) case is focused on organic agriculture, with organic certification bodies, organic farmers and public bodies to overlook that organic certification is in line with legal requirements (Official Gazette RS 30/2010; fully aligned with EU regulation on organic farming - Regulation EC 834/2007). The RECAP platform will support the entire process of subsidy provision for organic farmers, certification agencies, agricultural consultants and for the public authorities tasked with implementing, managing and controlling this payment scheme. Serbia being an EU candidate country (2012), has started accession negotiations in 2014 and is committed to transpose and implement the acquis on agriculture and rural development by the date of accession. RECAP platform will be positioned to support monitoring aspects of relevant subsidies within the Instrument Pre-Accession Assistance in Rural Development (IPARD) and providing assistance for the implementation of the acquis concerning the CAP.

The outcomes of the Pilot contribute to the achievement of the strategic impacts of the RECAP project: the stimulation of the creation, delivery and use of new services coupled with open public data; the delivery of more personalised public services that better suit the needs of users; the reduction of the administrative burden of citizens and businesses and the increased transparency of and trust in public administrations. The achievement of the impacts was measured through the monitoring of a set of result and impact indicators, shown in Table 3 below.

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43 Case study participants reported that initially, RECAP was aiming to develop a platform with a common interface and features for the delivery of public services. However, based on the results derived from the users’ needs analysis and co-production of services in all pilot countries, the technical team designed and developed five different interfaces/workflows customised to the specific needs of each of the five countries’ users. (Source: Pers. Comm. Case study participant, Dimitrios Petalios (CREVIS), June 2018)

Table 3. Result and Impact Indicators for the Pilots

<table>
<thead>
<tr>
<th>Indicator</th>
<th>Measurement technique</th>
<th>Total target value</th>
<th>Target achieved</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of farmers in pilots</td>
<td>Demonstration in 5 pilot sites</td>
<td>635</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of cross compliance inspections carried out remotely with RECAP</td>
<td>Demonstration in 5 pilot sites</td>
<td>305</td>
<td>Yes</td>
</tr>
<tr>
<td>Number of on the spot checks carried out with RECAP</td>
<td>Demonstration (RECAP vs Business As usual Scenarios) in 5 pilot sites</td>
<td>115</td>
<td>Yes</td>
</tr>
<tr>
<td>Reduction of administrative cost for payment agencies</td>
<td>Demonstration (RECAP vs Business As usual Scenarios) in 5 pilot sites – Evaluation of Results</td>
<td>&gt;25%</td>
<td>Generally yes, see discussion below</td>
</tr>
<tr>
<td>Reduction of administrative burden for farmers</td>
<td>Demonstration (RECAP vs Business As usual Scenarios) in 5 pilot sites – Evaluation of Results</td>
<td>&gt;25%</td>
<td>Generally yes, see discussion below</td>
</tr>
</tbody>
</table>

Source: RECAP initiative case study participants.

A monitoring and evaluation system (qualitative and quantitative tools) was used to ensure on the one hand the proper development of the Pilots to achieve the expected outcomes, and on the other hand to allow assessment of whether the specified result and impact indicators have been achieved and obtain relevant inputs for the RECAP solution sustainability and future adaptations.

The first three targets (number of farms participating in pilots, number of cross-compliance inspections carried out using RECAP, number of OTSC carried out using RECAP) have all been achieved. Upon completion of the pilot, participants were surveyed about their perceptions about the extent to which the RECAP platform reduces administrative burden and facilitates compliance. Selected results from this survey are:

- 61% of farmers participating in the RECAP pilot somewhat agreed or strongly agreed that the RECAP platform increases their understanding of CAP Cross-Compliance (CC) rules, and 55% somewhat or strongly agreed that the platform decreases the likelihood of their breaking CC rules.

- 42% of agricultural consultants participating in the pilot reported that the necessary time for preparing Basic Payment Scheme (BPS) application will be shorter using the platform; and the corresponding time reduction is >25% for 60% of this subset; the remaining 44% considered that time spent preparing applications would not change. Similar results were found in relation to time spent checking adherence to CC rules.

- 51% of participating farmers considered that their necessary time for preparing a Basic Payment Scheme (BPS) application would be shorter using the platform (and 64% of this subset of farmers considered that the corresponding time reduction would be greater than 25%); compared to 44% of farmers who considered the time spent would not change, and 5% who considered their time spent making an application would be longer. Similar results were found in relation to time spent checking adherence to CC rules.

- 82% of organic farmers somewhat or strongly agree that the platform increases their understanding of compliance with Organic Certification and Organic Subsidies; 77% believe it will help them to follow organic certification requirements, and 91%

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believe that using the system will reduce time for presenting evidence of compliance with Organic Certification requirements.

- 74% of inspectors somewhat or strongly agree that the platform makes the CC procedure more transparent, while 68% believe the platform increases the accuracy of OTSC for CC;
- 62% of inspectors consider the time spent inspecting a farmer would be shorter using RECAP, and of these, 60% considered the time reduction would be greater than 25%. Similar results were found in relation to the number of plots inspected per day.
- 58% of inspectors somewhat or strongly agree that the platform allows for the reduction of administrative burden for inspectors.
- 100% of certification bodies somewhat or strongly agree that the platform will assist them with Organic Certification and that it reduces administrative burden.

_Future plans for RECAP and beyond_

The outcomes of the RECAP pilots were presented at the EU’s 2018 INSPIRE Conference.\(^\text{46}\)

While the RECAP initiative formally concluded in 2018, there are a number of further EU initiatives which, like RECAP, aim to simplify and modernise administration of the CAP. Box 2 provides details.

Box 2. Further EU collaborative initiatives for innovative tools for CAP 2020+

The RECAP initiative, which commenced in 2016, is a forerunner in what has become a very active research and innovation space within the European Union. Since that time, a number of collaborative initiatives have commenced, which aim to encourage new tools and processes for modernising and simplifying the CAP in the next programming period (beginning 2020) and beyond. Key initiatives are:

- **Pilot4CAP** is a platform for sharing Pilot projects for the new CAP2020+, hosted and coordinated in the G4CAP Web application. This platform calls for sharing and reporting of publicly known new or ongoing pilot projects performed in preparation for the new CAP 2020+. Projects on the following subjects can be entered: IACS, OTSC, LPIS, Land Use, Land Cover, (IT or other) services making use of imagery such as Sentinel optical, Sentinel radar, VHR/HR satellite, aerial photo, RPAS or High Altitude drones (HADs).

The Sentinels for Common Agricultural Policy (Sen4CAP) project, launched in May 2017, aims at “providing to the European and national stakeholders of the CAP validated algorithms, products, workflows and best practices for agriculture monitoring relevant for the management of the CAP. The project will pay particular attention to provide evidence how Sentinel derived information can support the modernization and simplification of the CAP in the post 2020 timeframe. Sen4CAP has been set up by ESA in direct collaboration and on request from DG-Agr, DG-Grow and DG-JRC.”

Sources: [https://g4cap.jrc.ec.europa.eu/g4cap/Default.aspx?tabid=354](https://g4cap.jrc.ec.europa.eu/g4cap/Default.aspx?tabid=354); [http://esa-sen4cap.org](http://esa-sen4cap.org);

Lessons learned

**Lesson 1:** Earth-observation tools powering accessible, user-specific platforms offer the opportunity to substantially reduce transactions costs of administering the Common Agricultural Policy.

As the results from the end-of-pilot survey showed, pilot participants (farmers, agricultural consultants, inspectors, certification bodies and national paying agencies) all generally considered that the RECAP platform would reduce administrative burden. In some cases, reductions in administrative costs (generally measured as time spent on various administrative activities) were considered to be greater than 25%.

**Lesson 2:** By using spatially-explicit earth observation and other data on a wide range of agricultural and environmental variables, RECAP paves the way for more nuanced, targeted agri-environmental policies.

Beyond lowering the administrative costs of implementing existing CAP programmes and requirements, RECAP-style digital platforms based on earth observation data enables public authorities to better monitor the implementation of agricultural and agri-environmental policies, and paves the way for more targeted policies in the future. In particular, the provision and availability of highly-differentiated spatial data (e.g. by parcel) on agricultural practices and landscape characteristics (e.g. slope, proximity to receiving waters, soil type, etc.) at high temporal frequencies will allow agencies to pursue more spatially and dynamically flexible policies that were previously infeasible due to data constraints.
Lesson 3: Digital tools such as the RECAP platform can increase the transparency of inspections and the accountability of public organisations, resulting in greater robustness of, and trust in, public agencies.

The RECAP platform provides access to frequently updated satellite data and to functions for inspectors or farmers so that they may upload geotagged, time-stamped images to support administrative checks of eligibility and compliance. Thereby, farmers have continuous access to further farm-related details within a secure and transparent framework. Further, farmers can use the images uploaded in a number of ways: e.g. share them with advisors and seek assistance or rectify non-compliance or prevent such a case occurring in the future.\(^{47}\) RECAP is therefore a tool that assists fair, transparent and detailed inspections.

Lesson 4: RECAP uses a co-operative approach to ensure the efficiency and effectiveness of its technical solutions, and interoperability with other solutions.

RECAP helps to foster a less adversarial administrative context by “building bridges” between public administrators and farmers through the use of innovative Earth Observation solutions and related tools. It is based on a user-driven approach with its solutions having been designed and developed alongside the end-users and stakeholders, under a co-creation and co-production scheme.

The collaborative approach also encourages proactive participation of farmers in the overall monitoring procedure, giving them an active role in the data collection process, enhancing close communication and co-operation with public administration. This innovative approach sets up a monitoring system that informs, guides and notifies farmers on their obligations towards the BPS regulations, instead of penalising them for non-compliance when inspections take place.

Finally, RECAP also offers an Application Programming Interface (API) allowing to other platforms to use the RECAP data or contribute data to the RECAP database. This allows for interoperability and interconnectivity with other platforms or applications offered by PAs as well as ensures further integration with other systems developed (or to be developed) by agricultural consultants. In this way, RECAP allows for the “only once” principle, according to which information submitted once by the farmers need not be asked for again by another service of the administration.\(^{48}\)

Lesson 5: Innovative digital solutions such as RECAP can underpin new private sector business models.

The innovative solutions that the RECAP platform provides to agricultural consultants give rise to new business opportunities. Provided with the Software Development Kit, agricultural consultants are offered certain functionalities allowing them to search and use data stored in the RECAP platform; to integrate search results into their applications supporting farmers’ claims; and to manage RECAP configuration and objects. Overall,

\(^{47}\) In theory, geo-tagged photos could also be used by farmers in support of an appeal. However, the use of geo-tagged photos to make an appeal may require changes to the existing EU CAP administrative and legislative frameworks. Consideration of such changes are beyond the scope of this case study.

\(^{48}\) Note that the RECAP platform does not ensure that administrations will not ask farmers to provide information already obtained, but the principle is that information provided into the RECAP platform will be available; i.e. the platform allows for, but does not intrinsically ensure, that the “once only” principle is implemented.
RECAP can be used as a tool to underpin the day-to-day work of agricultural consultants to provide valuable advice to farmers.

References


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Case study 5: Digital technologies applied by USEPA to achieve Innovative Compliance

Case study objective

The objective of this case study is to provide a practical example of how digital technologies and data transparency tools can be used as part of a broader strategy to improve the flexibility and robustness of regulatory environmental programmes.

Context: the policy environment

The United States Environmental Protection Agency (USEPA) implements national environmental law by writing and enforcing regulations, setting national standards that US states and tribes enforce, and assisting regulated entities to understand the requirements (USEPA, date NA). As such, USEPA (together with the United States Department of Agriculture (USDA)) is one of the key national bodies tasked with implementing US agri-environmental policy. USEPA administers a range of US federal legislation relevant to agriculture, which has both regulatory and non-regulatory components (see additional description below).

Use of digital technologies to support

The problems

Evaluation of compliance and enforcement programmes is an important activity for any regulator. During 2010-2013, USEPA self-identified a range of issues or areas for applying innovative compliance approaches, including: “gaps in information about the compliance status of regulated entities, unacceptably high rates of noncompliance, deficiencies in state enforcement of delegated programmes, and substantial shortcomings in managing (collecting and transmitting) compliance-related information” (Markell and Glicksman, 2015[29]).

These problems are not unique to USEPA, and relate to fundamental challenges caused by transactions costs, information gaps, information asymmetries, and incentive misalignment between the regulator and the regulated community.49

The solutions

To address these gaps in the existing compliance and enforcement approach and improve the cost-effectiveness of USEPA’s compliance programme, USEPA began systematically exploring innovative compliance tools in 2012 and activities such as the use of optical gas imaging cameras, electronic reporting, and working to improve the effectiveness of regulations and permits, have become more commonplace. Types of tools are:

49 While this case study focuses on USEPA’s activities in the regulated context, it is worth noting that many elements discussed here are relevant to non-regulatory contexts. For example, to improve the efficiency and effectiveness of voluntary programmes.
- **Advanced monitoring and information technologies**: real-time continuous monitoring generates actual measurements (as opposed to estimates), which reduces information gaps and information asymmetries between the regulator and the regulated entities (see Box 5.1 for additional explanation).

- **Electronic reporting**: e-reporting saves time, reduces error, enables automatic checks & triaging to help target monitoring and enforcement activities, reducing transaction costs of compliance and enforcement activities. The use of two-way digital communication between regulator and regulated entity could allow the regulator to provide targeted compliance assistance.

- **Transparency—public disclosure requirements**: increased public disclosure provides incentive for entities to improve their environmental performance via reputation effects. Examples include USEPA’s ECHO database and EnviroAtlas, developed collaboratively by USEPA, United States Geological Survey (USGS), United States Department of Agriculture (USDA) and LandScope America (USEPA, 2017). However, care must be taken to ensure no privacy interests are compromised.

- **Rule and permit design—“Compliance-ready” technology and rules with “compliance built in”**: recognizing that enforcement action alone will not produce full compliance in every instance, this component entails promoting the use of technology, transparency, and other tools. Similarly, rules can be designed to require use of certain technology or processes by upstream manufacturing rather than attempting to regulate the use of technology by end users, e.g., auto manufacturers are required to install pollution control devices rather than requiring automobile buyers to do so. (Giles, 2013)

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50 See Hindin et al., 2016.

51 See [https://echo.epa.gov/](https://echo.epa.gov/), accessed August 2018. The Enforcement and Compliance History Online (ECHO) database provides “integrated compliance and enforcement information for over 900,000 regulated facilities nationwide. Its features range from simple to advanced, catering to users who want to conduct broad analyses as well as those who need to perform complex searches.” Specifically, ECHO allows users to find and download information on specific facilities; find EPA enforcement cases; analyse compliance and enforcement data; access data services and inform EPA.

52 See [https://www.epa.gov/enviroatlas](https://www.epa.gov/enviroatlas), accessed August 2018. EnviroAtlas is an interactive online platform comprising “tools [that] allow users to discover, analyse, and download data and maps related to ecosystem services, or the benefits people receive from nature.”
Box 5.1. Potential uses and use tiers of advanced monitoring data

(Performance and quality requirements for these uses may vary.)

**Directly Support Regulatory Programmes**
- **Permitting**: Part of record for issuance of rules or permits
- **Regulation and Compliance**: Identification of nonattainment areas/impaired waters; removal of designations when conditions improve; self-monitoring pursuant to a permit or an applicable rule
- **Enforcement**: Evidence in an enforcement action

**Aid or Supplement Regulatory Action**
- **Action Prioritization**: Targeting, development, and prioritisation of enforcement actions
- **Problem Identification**: Hot-spot identification and characterization, or analysis for programme planning purposes or future regulatory action
- **Additional Data**: Supplement current regulatory monitoring for planning
- **Emergency Response**: Pollutant identification, characterization of conditions and risks, response action planning, and status assessment following a response
- **Temporary Source Monitoring**: Temporary monitoring (e.g., construction sites)

**Educate/Inform the Public**
- **Programme Evaluation**: Evaluation of research, programmes, and other policy outside of regulatory actions
- **Transparency**: General information made available to the public about their environment

**Other Uses**
- **Facility Self-Monitoring**: Use to inform operational control by facilities (e.g. drinking water systems)
- **Personal Health**: Personal exposure monitoring and crowdsourced networks
- **Education**: Use of technology as a teaching tool (e.g. Science, Technology, Engineering, and Math [STEM] education)
- **Research**: Use by universities and others for research purposes
- **Hazard Alert Systems**: Alert building occupants of a problem

*Source*: Reproduced from Hindin et al. (2016[32]), Table 1, p.3.

*Note*: While all of these uses of advanced monitoring data can be applied to the agri-environmental context, discussion in the original article was not sector specific.

**How does innovative compliance apply to agriculture in the United States?**

Use of innovative compliance tools for agri-environmental policy implementation can broadly be separated into applications in regulatory (permit) and non-regulatory (voluntary) contexts. These are discussed in turn below, with primary emphasis given to the regulatory context.
Permitted agricultural operators and chemical input suppliers

In the US agriculture sector, some concentrated animal feeding operations (CAFOs) such as certain feedlots, dairies and poultry houses are “regulated by EPA under the Clean Water Act in both the 2003 and 2008 versions of the ‘CAFO rule’” (40-CFR) (NRCS, date NA). These regulations underpin a permitting system known as the National Pollutant Discharge Elimination System (NPDES). Innovative compliance tools are applied for NPDES permittees via several avenues:

- **Electronic reporting:** in September 2015, USEPA introduced electronic reporting for NPDES permittees (USEPA, date NA). This is being implemented in two phases, the first of which became operational in December 2016 (40 CFR § 122.41(l)(4)(i)). Permittees are required to submit certain documentation via an online portal known as NetDMR. Data reported electronically is made available to the public via the USEPA’s ECHO website.

- **Innovative compliance components in permitting:** permits (e.g. NPDES permits) generally operate on a 5 year cycle. As permits are renewed, innovative compliance elements such as data reporting requirements or use of new technologies could be introduced into the permit. Innovative compliance elements have been introduced for certain non-agricultural permittees. Law or regulatory changes may be required to facilitate broader adoption of innovative compliance approaches in permits.

- **Innovative compliance tools used in rule-making:** innovative compliance components could be introduced into rules applying to regulated agricultural enterprises (e.g. NPDES-permitted CAFOs), for example by updating rules to allow or require regulated businesses to make use of state-of-the-art technology, to require more transparency via public reporting, or to design new compliance pathways. However, USEPA’s Office of Water (USEPA OW), who administers the CAFO-related rules under the Clean Water Act, has no CAFO-related rulemaking underway at this time, and hence an opportunity to consider the application of innovative compliance principles in this arena has yet to arise.

Agricultural operators participating in voluntary programmes and initiatives

Agricultural enterprises that are not required to obtain a permit may nevertheless choose to participate in a range of voluntary agri-environmental programmes, such as cost-share programmes administered by the USDA Natural Resource Conservation Service (NRCS), water quality trading programmes, and other federal, state or local programmes which aim

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54 Note that NPDES applies to more than CAFOs; however this case study focusses on the agriculture sector.


56 See [https://echo.epa.gov/](https://echo.epa.gov/), accessed August 2018.

to incentivise production of environmental goods on working agricultural lands and/or the conversion (or “retirement”) of agricultural to other land uses such as forest or wetland.

In this voluntary context, when a producer enters into a voluntary contract for provision of environmental goods, innovative compliance tools can be used in much the same manner as in a regulatory context, with compliance with the terms of the contract taking the place of compliance with a permit. Certification programmes (e.g. organic labelling) can also implement innovative compliance tools as part of the certification process. Programme administrators and producers can also make use of some of the innovative compliance tools—particularly electronic reporting in conjunction with transparency—to foster public support for entirely voluntary environmental efforts (i.e. even those which do not use contracts or any other form of legal enforcement mechanism).

Beyond this, USEPA is also active in a range of initiatives to advance technologies which reduce environmental impacts from agriculture. Examples include:

- USEPA’s Office of Water is involved in a voluntary partnership effort with USDA and animal agriculture industry to find innovative solutions to recycling nutrients.  
  
- USEPA is assisting the Nebraska Department of Environmental Quality and Kansas Department of Health and Environment on the initiative “Use of Next-Generation Molecular Tools for Harmful Algal Blooms and Microbial Source Tracking to Support Watershed Restoration in Kansas and Nebraska”. This initiative aims to improve microbial source tracking and harmful algal bloom assessments using the PhyloChip, an innovative monitoring technology.  

**Lessons learned for the application of innovative compliance tools in agri-environmental contexts**

**Lesson 1: Design principles for EPA’s innovative compliance**

The first lesson comprises key design principles on which the innovative compliance initiative was based, such as:

4. Be sure regulated entities, the public, and the government can easily identify who is regulated and what they need to do to comply with the requirements. Where possible, use physical design, feedback technology, and/or self-implementing consequences to make compliance easier than non-compliance.

5. Require regulated entities to monitor factors that affect compliance and take steps to prevent noncompliance.

6. Provide the public and government agencies with real-time information on regulated entities’ emissions, discharges and key factors that affect compliance and outcomes, leveraging accountability and transparency.

7. Use market forces, benefits of demonstrated compliance, and other incentives to promote compliance.

For more information, see Hindin and Silberman (2016[33]).

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Lesson 2: Good regulatory practices can be transferrable across different kinds of regulations.

Case study participants noted that one of the earliest activities in the innovative compliance initiative was to consider what kinds of innovations in enforcement and compliance techniques were being pursued by other regulators, both within the US and internationally. Case study participants commented that the innovative compliance effort reviewed academic literature and engaged directly with many regulators, but that judgement was needed to identify which tools could be adapted to the USEPA context. For example, the research identified that the use of third party reporting by the United States Internal Revenue Service (IRS) to improve compliance with US taxation law is a tool that can be also used by USEPA in the context of enhancing compliance with environmental law. They also drew on MIT research in Gujarat India which found that third party auditors must be independent and have results checked to produce reliable audits (Duflo et al., 2013[34]).

Lesson 3: Technological change offers new possibilities for improved monitoring and compliance. However, there needs to be clear and fit-for-purpose processes for demonstrating suitability of advanced monitoring tools for regulatory purposes, which may differ from existing processes. This may be challenging to achieve in a context of fast-paced technological change.

Technology requirements, whether the technology is used to address or monitor pollution, are not a new feature of environmental regulation. Recent technological innovations are delivering new technologies for monitoring regulated entities’ environmental performance and compliance with regulatory requirements. New monitoring devices are often smaller and more portable technologies, and are declining in cost. Further, the real innovation is that these technologies can be linked to information communications technology (ICT) that delivers data in real time, and can allow for the automating of alerts (e.g. via mobile telephones) that can help a facility fix problems before noncompliance occurs.

Regulations can shape the uptake of technologies in several ways, including by mandating use of a particular technology in a certain context (technology mandate) or setting standards that technologies are required to meet (technology performance standards). It is acknowledged that some USEPA programmes generally now use performance standards that technologies must meet, rather than mandating use of specific technologies.60 Technological requirements, or standards that technologies must meet (in a regulatory context), are generally specified via USEPA rules and in manuals (e.g. the NPDES permit writers’ manual61). Rule-making processes can be lengthy and costly.

Interest in using new technologies for monitoring the environmental performance of agriculture, particularly continuous monitoring systems, is rising, not only in the United States but elsewhere: for example, the EU Commission recently introduced regulations to permit use of remote sensing technologies to supplement (or eventually substitute for) on-


61 See https://www.epa.gov/npdes/npdes-permit-writers-manual-0, accessed August 2018. See Chapter 8 for Monitoring and Reporting Conditions, including specification of minimum requirements for monitoring and testing methodologies.
the-spot-checks of environmental and other conditions under the Common Agricultural Policy.\textsuperscript{62}

Given this interest, and the rapid pace of technological change of relevant technologies, existing processes for vetting new technologies for regulatory purposes, particularly ones which take several years to complete, need to become more agile. Environmental regulators and policy administrators could better engage with the regulated community, the private sector and researchers to develop “testbed” environments for assessing the potential of technological advances in regulated contexts. Further, processes for vetting new technologies should be clear for all participants and allow for unanticipated technological change (e.g. new types of sensors currently un-envisioned).

Regulators could also consider providing incentives for the regulated community to voluntarily participate in testing and adoption of new technology for both monitoring and reducing environmental impacts.

\textit{Lesson 4: Take a holistic approach: use of digital technologies complements non-digital, and regulatory efforts can work alongside voluntary efforts.}

As detailed above, USEPA’s efforts to improve regulatory compliance are being complemented by efforts to support agriculture to improve its environmental impact outside the regulatory context. While this particular approach reflects the legislative and policy environment specific to the United States—particularly the fact that, to a large extent, agriculture is exempted from a range of environmental regulatory requirements that are placed on other industries (Breggin and Myers, 2013\textsuperscript{[35]}—having a coherent approach across regulatory and non-regulatory contexts can have a wide range of benefits (OECD, 2008\textsuperscript{[36]}). These include ensuring that voluntary approaches such as emissions or water quality trading are not stymied by rigid regulatory requirements (see Stephenson and Shabman, 2017\textsuperscript{[37]} for a discussion), and allowing sharing of enforcement experience and expertise between regulators and voluntary programme administrators (who may, for example, need to enforce conservation contracts in agri-environmental payment schemes or verify credit creation in trading schemes).

Also, advances in digital technologies (e.g. the PhyloChip technology) are being pursued alongside other technologies which may have no digital component. It is important to recognise that in many cases digital tools are a way to encourage farmers and others to take environmentally beneficial non-digital actions. That is, better measurement, especially when connected to IT communication tools, can help focus attention and actions where they will be most effective. As such, investment in digital tools should be seen as a complement to, not a substitute for, non-digital technologies or other non-technological innovations which directly improve environmental outcomes.

References


Case study 6: Digital innovations to facilitate farm level data analysis while preserving data confidentiality

Case study objective

The case study objective is to show how recent innovations such as “confidential computing” can improve access to farm-level data for agricultural and agri-environmental policy or research, while appropriately maintaining data confidentiality and security. While recognising that there are many relevant innovations around the globe, this case study provides examples drawn from the experience of Australia’s Commonwealth Scientific and Industrial Research Organisation (CSIRO), a world leader in these emerging technologies.

Context: farm-level data is crucial for policy analysis, but high confidentiality requirements limit the ability to use it

Micro-level agricultural data (for example, farm level or field level data) is needed for evaluating the effectiveness and efficiency of agricultural and agri-environmental policies. They also allow understanding of how policy impacts differ across dimensions such as location, production practices, industry or sector, socio-economic status, etc.

Agricultural censuses and surveys conducted by or on behalf of government agencies have long been a key source of such data. Most countries, including OECD countries, have a long history of gathering such data and using it to underpin policy decisions. However, in general, authorising legislation or regulation which enable this data collection also impose strict confidentiality requirements on the public release of records which could (whether intrinsically or when combined with other data) identify individuals or individual businesses (farms).

In addition to such datasets, administrative data, usually gathered and held by government agencies, is an important source of information relevant for policy-making. Berg and Li (2015[38]) identify the following sources of administrative data for agriculture: soils information; crop insurance and subsidiary programmes; land registration and cadastral records; government regulations and monitoring programmes; private and non-governmental organizations and sources of operations; reporting systems (e.g. periodic crop condition reporting); and taxation data. Access to administrative data is often even more limited than access to farm level survey or census data.

Data confidentiality requirements are often cited in the literature as a limiting factor in micro-level agricultural and agri-environmental analysis (Martínez-Blanco et al., 2014[39]) (Tukker and Dietzenbacher, 2013[40]) (VanderZaag et al., 2013[41]). Further, researchers and

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63 OECD (n.d.[75]) defines “administrative data” to have the following features:

- the agent that supplies the data to the statistical agency and the unit to which the data relate are usually different: in contrast to most statistical surveys;
- the data were originally collected for a definite non-statistical purpose that might affect the treatment of the source unit;
- complete coverage of the target population is the aim;
- control of the methods by which the administrative data are collected and processed rests with the administrative agency.
analysts often need to be able to link different datasets in order to conduct policy-relevant analysis. In the agriculture context, one crucial type of linking is to tie data on physical characteristics (e.g. location-specific data on soil type, precipitation, temperature, proximity to water bodies, etc.) with data on economic characteristics (e.g. farm performance attributes such as farm profit, farm costs; subsidies received; input use, etc.). This linkage generally needs to occur at the farm or field level in order to evaluate policy microeconomic and environmental impacts (Jones et al., 2017[42]; Petsakos and Jayet, 2010[43]). Woodard (2016, p. 385[44]) sums up the situation: “Some work cannot be feasibly accomplished without being able to link together different databases at low levels of aggregation.” While confidentiality requirements for individual organisations or individual datasets are often the reason that desired linkages across datasets cannot be made, a range of other factors also contribute, including: the absence of common linking variables (which enable record matching) (Lubulwa et al., 2010[45]); high costs or lack of resources or expertise needed to perform the linkages (Hand, 2018[46]); and lack of interoperability between datasets (e.g. different definitions with no rule to “translate” definitions in one dataset to match up with another) (Hand, 2018[46]).

Use of digital technologies to overcome the impasse

The problems

Efforts to increase the accessibility and reusability of agricultural micro data, and to link different sources of agricultural micro data, seek to address issues arising from information gaps and information asymmetries.64 However, in doing so, they create new issues. At a conceptual level, ethical and practical65 questions about the appropriate level of confidentiality or privacy protection for farmers (and other entities to which data refer) must be considered.66 This then presents additional technical issues about:

- how to appropriately protect farmers from the misuse of data that pertains to them (a question with both competitiveness (economic) and ethical dimensions);
- how to ensure farmers are able to exercise their right to privacy or confidentiality; and
- how to make datasets interoperable.

64 McCaa and Esteve (in Eurostat, 2006, p. 44[78]) (citing Julia Lane (2003) highlight “five classes of benefits which accrue from broader access to microdata: address more complex questions, calculate marginal effects, replicate findings, assess data quality and build new constituencies or stakeholders. Replication is extremely important because there is an overwhelming temptation for scientists to misrepresent results when the data are unlikely to be available to others.”

65 “Beyond law and ethics, there are also practical reasons for statistical agencies and data collectors to invest in this topic: if individual and corporate respondents feel their privacy guaranteed, they are likely to provide more accurate responses.” (Domingo-Ferrer and Fraconi, 2006[79])

66 It is acknowledged that in some cases there may be little scope, at least in the short to medium term, to alter existing levels of protection provided confidentiality requirements already set in data collecting agencies’ authorizing legislation. Nevertheless, as opportunities to review such legislation arise, the appropriate level of protection should be carefully considered and not take as a “given”.
Researchers from the USDA’s ERS succinctly define the challenge:

“In essence, the trade-offs involve the desire to get the highest return possible for substantial data collection costs and respondent burden to gather information necessary to produce official statistics and support economic research on one hand and the requirement to uphold the pledge of confidentiality and ensure the future participation of respondents.” (Towe and Morehart, n.d., p. 2[47])

**Digital solutions**

**Existing approaches to improving data access and reuse while preserving confidentiality**

Technology solutions have been developed over many years to enable more data to be available for use, such as anonymisation and data obfuscation techniques, and this activity continues today, with many exciting technologies for improved data availability on the horizon. Existing methods for protecting data include simple methods such as aggregation and suppression, such as only releasing data at postcode level and only with a sufficient number of counts. These methods can be augmented with perturbation methods,\(^{68}\) which protect tables released from unit level census data from re-identification attacks.\(^{69}\)

There are a large number of proposed approaches to confidentialisation to facilitate data sharing for research while protecting privacy. All of these have been used in successful, large scale implementations in Australia and internationally (O’Keefe and Rubin, 2015[48]; Reiter and Kohnen, 2005[49]). Relevant arrangements include:

- De-identified open data access – the analyst downloads the data directly (e.g. datasets accessible via the GODAN initiative\(^{70}\))
- User agreements for offsite use (licensing), in which users are required to register with a custodian agency, and sign a user agreement, before receiving data to be analysed offsite.
- Remote analysis systems, in which the analyst submits statistical queries through an interface, analyses are carried out on the original data in a secure environment and the user then receives the (confidentialised) results of the analyses.

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\(^{67}\) The material in this section is taken from CSIRO’s 2016 *Submission to the Australian Government Productivity Commission’s Inquiry into Data Access and Use* (Chapman, 2016, pp. 22-25, 39[74]), with minor editorial modifications and addition of examples that are relevant to the agri-environmental context. Changes have been approved by the original authors.

\(^{68}\) *Perturbation methods* such as swapping, recoding, etc. make “exceedingly unlikely the identification of individuals, families or other entities in the data. Technical [perturbation] measures have the additional benefit that any assertion of absolute certainty in identifying anyone in the data is false.” (Eurostat, 2006, p. 40[78])

\(^{69}\) *Re-identification attacks* are methods of analysing aggregated data to extract the details of a single individual or a group of individuals with a common characteristic. A notable example is the re-identification of the Netflix public dataset as performed by Narayanan and Shmatikov, [https://www.cs.cornell.edu/~shmat/shmat_oak08netflix.pdf](https://www.cs.cornell.edu/~shmat/shmat_oak08netflix.pdf).

\(^{70}\) The Global Open Data for Agriculture and Nutrition (GODAN) initiative promotes the “the proactive sharing of open data to make information about agriculture and nutrition available, accessible and usable” See [https://www.godan.info/](https://www.godan.info/), accessed August 2018.
• Virtual Data Centres (VDCs), which are similar to remote analysis systems, except that the user has full access to the data, and are similar to on-site data centres, except that access is over a secure link on the internet from the researcher’s institution. (e.g. the USDA-ERS data enclave platform provided by NORC,\(^{71}\) Australian Bureau of Statistics DataLab\(^{72}\)). VDCs may also make use of containerisation, where the analyst can access the data in a limited way, on a secure platform through a containerised application (e.g. the SURE platform used by the Sax Institute\(^{73}\)).

• Secure, on-site data centres, in which researchers access confidential data in secure, on-site research data centres (e.g. the Secure Access Data Center, France\(^{74}\)).

Each arrangement makes data available at a specified level of detail, where sensitive detail can be reduced by methods including:

• Removal of identifying information
• Confidentialisation of the data by one of a range of methods, including aggregation, suppression or the addition of random “noise”
• Replacement of sensitive variables or data with synthetic (“made-up”) data.

Unfortunately, with the exception of the open data approach, these mechanisms greatly restrict the number of people that can access the data, and the convenience of that access. Also, some techniques may reduce the value of data for policy analysis, for example by reducing the level of granularity, introducing bias into the dataset, or reducing the ability to link individual records in different datasets.

\(^{71}\) “The [United States] Economic Research Service (ERS) and the National Agricultural Statistics Service (NASS), in coordination with the Food and Nutrition Service (FNS) utilise the [university of Chicago’s NORC] Data Enclave to provide authorised researchers secure remote access to data collected as part of the Agriculture Resource Management Survey (ARMS), the primary source of information to the US Department of Agriculture and the public on a broad range of issues about US agricultural resource use, costs, and farm sector financial conditions.” See http://www.norc.org/Research/Projects/Pages/usda-ers-data-enclave.aspx, accessed August 2018.

\(^{72}\) “The DataLab is the data analysis solution for high-end users who want to undertake interactive (real time) complex analysis of microdata. Within the DataLab, users can view and analyse unit record information using up to date analytical software with no code restrictions, while the files remain in the secure ABS environment. All analytical outputs are checked by the ABS before being provided to the researcher.” See http://abs.gov.au/websitedbs/D3310114.nsf/home/CURF:+About+the+ABS+Data+Laboratory+%28ABSDL%29, accessed August 2018.

\(^{73}\) SURE is “Australia’s only remote-access data research laboratory for analysing routinely collected [health-related] data, allowing researchers to log in remotely and securely analyse data from sources such as hospitals, general practice and cancer registries.” See https://www.saxinstitute.org.au/our-work/sure/design-and-functionality/, accessed August 2018.

\(^{74}\) See https://www.casd.eu/en/, accessed September 2018. This is the channel for accessing agricultural micro-level data in France, including FADN data, but also surveys of farm practices. The CASD has been in place since 2012 and contains various types of sensitive data (e.g. health, taxation, business surveys, and administrative data such as agri-environmental measures).
Recent technological advances: Confidential Computing, Multi-party Computation and Synthetic Data Release

The Commonwealth Scientific and Industrial Research Organisation (CSIRO), a corporate entity of the Australian Government, is currently leading research into several innovative techniques for allowing researchers to make use of confidential data such as farm level records, without actually being able to see or access the raw data. These innovations rely on advances in digital encryption to preserve confidentiality.

Confidential computing and multi-party computation

CSIRO has expertise in homomorphic encryption, which enables calculations to be done on data while the data is encrypted; and secure multi party computation, which allows data to be shared between and computed on by multiple parties, but none of the parties have sufficient information to reconstruct the data itself. Both of these approaches are considered very promising as a long term solution to the data protection problem, however “fully homomorphic encryption”, which is a recently discovered capability, is not yet practical for large scale data analysis problems.

As part of its “confidential computing” platform, CSIRO Data61 is developing a combination of “partial homomorphic encryption” (which is more limited but more efficient than fully Homomorphic encryption), distributed computing and machine learning. This platform enables the provision of services that allows individual organisations (both public and private) to do joint analysis of data without exposing their own data to any other party. These methods are being applied to federal government data within the Australian Government National Innovation and Science Agenda (NISA) framework as a proof of concept.

The “Confidential Computing” platform allows access to a prescribed set of analytics functions that are performed over encrypted data that is not disclosed to the data scientist or analyst. As of September 2018, analytics functions that are available through this approach include aggregation and other simple statistical functions, simple supervised and unsupervised machine learning approaches, but currently exclude methods such as Random Forests and Deep Learning due to their incompatibility with the reduced set of operations available from the underlying cryptographic representation of the data. Confidential Computing enables a new, low friction, method of doing exploratory linkage and analysis of datasets. This approach may allow the discovery of new connections between datasets or attributes and insights without the overhead of the training, authorisation and provision of current approaches, while still maintaining the confidentiality of the data. More expensive access to the data directly can still be obtained through current methods, particular if justified through exploratory analysis over encrypted data. This capability is equally relevant to intra-government data collaboration, government-private data collaboration, and private-private data collaboration.

Synthetic data release

There is a recent advance in privacy technology known as Differential Privacy, introduced by Dr Cynthia Dwork at Microsoft. Differential Privacy is a quantifiable measure of the privacy of certain data analytics techniques that involve random perturbation of either the data being analysed or the analysis itself. CSIRO Data61 is working on a variety of

differentially private mechanisms to allow the release of synthetic unit record datasets that contain statistically similar data to the original data, but can guarantee that the released data cannot be re-identified. Data61 is undertaking investigation of these methods within the NISA framework to potentially allow the release of government datasets with fewer restrictions than are currently needed to ensure confidentiality. These techniques involve adding noise to the data, and so have some impact on the utility of the data for analytics.

Lessons learned for the use of innovative digital technologies to improve access to and reusability of farm level data for policy-relevant analysis

Lesson 1: Agricultural micro data, and the ability to “tie” farm level financial data to physical data, including location-specific attributes, are crucial for developing more efficient, spatially-targeted policies.

Given the weight of evidence from existing economic analyses that untargeted agricultural policies are inefficient (see, for example, (Arbuckle, 2013[50]) (Lankoski, 2016[51]) (OECD, 2008[52]) (OECD, 2012[53]) (Rabotyagov et al., 2014[54]) (Weersink and Pannell, 2017[55]) (Whittaker et al., 2017[56]), the usefulness of micro-data for effective and efficient policy design, implementation and evaluation will only increase.

Governments need to recognise that access to agricultural micro data, including the ability to link different agricultural micro datasets (as well as other relevant data such as environmental data) is a crucial source of value-added, and is needed to produce robust and targeted policy analysis and advice.

Lesson 2: Even though governments may be moving towards more open data approaches, access to farm level data collected by public agencies is generally limited by enabling legislation and is underpinned by trust.

Many governments have decided to pursue more “open data” approaches or enact general data privacy regulations which will shape governance on the use of agricultural micro data. Many have also committed to the principle that published data should confirm to FAIR standards\(^76\) of being findable, accessible, interoperable and re-useable.\(^77\) However, it is important to appreciate that government organisations are often legally required to maintain confidentiality in relation to raw data (particularly, in the agriculture context, where the raw data pertains to individuals or individual farms), and hence that commitments to open data or FAIR principles may not be considered relevant for access to farm-level data.

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\(^77\) In the Australian context, the Australian Government released in 2015 the *Australian Government Public Data Policy Statement*. The Policy Statement states: “The Australian Government commits to optimise the use and reuse of public data; to release non sensitive data as open by default; and to collaborate with the private and research sectors to extend the value of public data for the benefit of the Australian public. Public data includes all data collected by government entities for any purposes including; government administration, research or service delivery. Non-sensitive data is anonymised data that does not identify an individual or breach privacy or security requirements.” (emphasis added).

Moreover, most agricultural data is collected via trust-based relationships between farmers and government agencies or researchers. In a voluntary context, there is a clear link between trust in the data collector’s commitment and ability to preserve confidentiality and the willingness to participate. In a mandatory context, while arguably participation could be more easily regulated, provision of complete, correct data may nevertheless be difficult to ensure.

The fact that government agencies’ (and researchers’) ability to collect farm-level data is based on trust and on often longstanding legislative commitments to maintaining confidentiality has several implications:

- Government may have limited ability to lessen these legislated confidentiality guarantees, especially in relation to existing datasets. This suggests that an open data approach for agricultural micro data may not be an achievable or desirable end goal.
- Government should consider how collection of data via new methods which do not require direct participation from farmers (e.g. collection of data via remote sensing, or automated collection of data from “smart” agricultural machinery or infrastructure) impacts on the existing trusted relationships with farmers. Interactions may not be straightforward – for example, increased use of remote sensing may induce farmers to become more relaxed about (certain aspects) of confidentiality because data is available to all; conversely, it could engender a more wary approach and resistance to what could be perceived as government overreach.

Lesson 3: By facilitating analysis of the data without the analyst being able to see the data, confidential computing can solve the confidentiality-reuse dilemma.

CSIRO’s N1 confidential computing platform provides an example of how technology can be used to bypass the traditional dilemma between the benefits of allowing access to highly disaggregated “true” data (including individual records) and the need to aggregate or perturb the data in order to preserve confidentiality. However, these technologies are still new and have yet to be applied in a context involving agricultural data.

Lesson 4: Improving access to agricultural micro data needs a coherent, tiered data dissemination strategy.

Existing arrangements for access to agricultural micro data for policy-related research and analysis is cumbersome and often fails to adequately provide researchers and analysts with the data they need. This results in duplication of effort (e.g. universities conducting their own surveys because they cannot access farm-level data collected by government statistical agencies) and limits the ability for researchers to provide targeted, dis-aggregated policy analysis and advice.

As demonstrated in this case study, there are a range of institutional and technological solutions which can facilitate access to agricultural micro data while preserving individual respondent confidentiality. It is not clear that one particular solution is superior; rather, government agencies (and other organisations who collect agricultural micro data) can take a graduated approach which takes into account both the benefits of allowing access to specific data for specific purposes and the potential harm caused if confidentiality is breached. Data dissemination strategies should explicitly recognise the trade-offs of different data access options.
It is suggested that governments take a tiered approach, as follows:

- Start from the position of open data and take a “Why not?” approach: that is, reasons why data cannot be openly provided should be clearly articulated. Pre-existing legislative requirements to protect confidentiality should be able to be periodically transparently reviewed.\(^78\)
- Invest in data services such as providing linked datasets to increase the usefulness of government data collections. One important aspect of this is to link farm financial datasets with physical data such as soils, precipitation, and other climate variables.
- Increase use of secure remote access mechanisms to reduce transactions costs of allowing trusted researchers to access micro data.
- Explore greater use of new technologies such as confidential computing that avoid the traditional confidentiality-accessibility dilemma.

Organisations who collect or house data should work together with data providers (e.g. farmers in the context of traditional agricultural surveys) and data users to establish a clear framework governing data access.

Finally, while this case study has not considered broader issues about data ownership, data use rights and requirements to obtain consent to use and reuse data, it is important to emphasise that frameworks governing access to agricultural micro data should be coherent with broader policies governing such issues, as well as with underlying legislation authorising government agencies to collect agricultural data. For example, if a government were to take an approach that gives farmers ownership of agricultural data which pertains to them, data dissemination strategies of government agencies who collect, store or disseminate agricultural data needs to be consistent with this broader approach. Another example relates to consistency across jurisdictions: for example, organisations that are part of the Farm Accountancy Data Network (FADN)\(^79\) should ensure their data dissemination strategies are as consistent as possible, to facilitate analysis across FADN countries.

\(^{78}\) Note that this recommendation does not presume that an open data approach will be appropriate in all cases. Rather, it is recommended as a useful conceptual starting point so that the case for confidentiality requirements can be re-evaluated and transparently made.

References


Case study 7: Data transparency, digital technologies and California’s water quality coalitions

Case study objective

The objective of this case study is to give a practical example of how data regulations and coalition-based water quality monitoring regimes can be used to underpin collective governance mechanisms to address nonpoint source environmental impacts from agriculture. These mechanisms strike a balance between lessening information asymmetries and gaps on the one hand, and protecting sensitive information and reducing regulatory burden on the other.

Context: the policy environment

California agriculture is extremely diverse, producing more than 400 commodities and spanning a wide array of growing conditions from northern to southern California. The state produces nearly half of US-grown fruits, nuts and vegetables, as well as exporting many agricultural products to markets worldwide. However, water discharges from agricultural operations (including irrigation runoff, flows from tile drains, and storm water runoff) can affect water quality by transporting pollutants, including pesticides, sediment, nutrients, salts (e.g. selenium and boron), pathogens, and heavy metals, from cultivated fields into surface waters. Many surface water bodies are impaired because of pollutants from agricultural sources. Groundwater bodies have suffered pesticide, nitrate, and salt contamination.

To prevent agricultural discharges from impairing receiving waters, the Californian Irrigated Lands Regulatory Program (ILRP) regulates nonpoint source discharges from irrigated agricultural lands. This is done by issuing waste discharge requirements (WDRs) or conditional waivers of WDRs (Conditional Waivers) to growers or groups of growers called Coalitions. Both WDRs and Conditional Waivers contain conditions requiring water quality monitoring of receiving waters and corrective actions when impairments are found. Further conditions require monitoring of agricultural runoff and impose reporting requirements – for example reporting on management practice implementation and nutrient application data (California Water Board, 2018). Enrolment in the ILRP is around 40,000 growers, or six million acres of agricultural working lands.80

Sections 13263 and 13241 of the Californian Water Code state that “economic considerations” is one of the factors a regional water board must take into account in issuing waste discharge requirements. Additionally, section 13267 requires the regional water board to ensure that “the burden, including costs, of [monitoring] reports shall bear a reasonable relationship to the need for the report and the benefits to be obtained from the reports.” (State Water Board, 2018, p. 10[57])

80 Adapted from: https://www.waterboards.ca.gov/water_issues/programs/agriculture/, accessed August 2018.
Refining data transparency requirements and use of digital technologies to deliver better outcomes for agricultural producers and water quality

The problems

The California State Water Resources Control Board’s (State Water Board) Policy for the Implementation and Enforcement of the Nonpoint Source Pollution Control Program\(^{81}\) (Nonpoint Source Policy) directs that any nonpoint source programme incorporate monitoring and reporting. The Nonpoint Source Policy “does not require any particular framework for monitoring and does not necessarily even require comprehensive ambient monitoring. But the nonpoint source implementation programme must ‘include sufficient feedback mechanisms so that the [regional water board], dischargers, and the public can determine whether the programme is achieving its stated purpose(s), or whether additional or different [management practices] or other actions are required.’ ”.

This requirement to undertake monitoring of agricultural runoff and receiving water bodies and reporting constitutes an effort to reduce information gaps about the quality of these waters, as well as the impact of agriculture on water quality. This data is crucial for the California Water Boards to achieve their mission “to preserve, enhance, and restore the quality of California's water resources and drinking water for the protection of the environment, public health, and all beneficial uses, and to ensure proper water resource allocation and efficient use, for the benefit of present and future generations” (State Water Board, n.d.\(^{58}\)).

However, these requirements are controversial to the agricultural community because they are costly to comply with and result in lessening of information asymmetries that producers may have incentive to maintain. Such incentive may occur for several reasons. One reason is that certain high-risk operations are subject to more rigorous management practices to minimise pollutants found in agricultural runoff and percolating water are required to address toxicity in receiving waters and nitrate associated with the over-application of fertilisers that has contaminated drinking water; since these additional requirements are costly, a producer may wish to avoid being identified as one of these high-risk operations. Another reason is that reporting on management practices risks disclosure of information that producers consider to be commercially sensitive. Finally, producers may be concerned that improved data on agricultural water quality impacts could be used to tighten regulations in future, resulting in increased regulatory burden and potentially negatively impacting the viability of agriculture in the region.

Therefore, the challenge for California Water Boards, who acknowledge the “critical importance” of agriculture in the region (Karkoski, 2012\(^{59}\)), is to balance “the need for transparency and measurable benchmarks” and maintaining acceptable regulatory outcomes on the one hand with ensuring regulatory burden is minimised and respecting “the need for the agricultural community to protect trade secrets and other sensitive information” on the other (State Water Board, 2018\(^{57}\)). This challenge is not unique to this context; it arises from the characteristics of existing agricultural production, which uses agricultural inputs (e.g. fertiliser and pesticides) and commercially sensitive information (e.g. fertiliser application regimes) to produce valuable outputs, but which also produce environmental externalities that are costly to address.

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The solutions

The Water Boards have devised a monitoring and reporting regime which aims to provide data for the required “sufficient feedback mechanisms”, while minimising regulatory burden and risks for producers related to information disclosure. This case study uses the example of the monitoring and reporting regime of the Central Valley Water Board, one of nine regional water quality control boards. The regional water boards operate semi-autonomously and are divided by watershed. The State Water Board works with the regional water boards and sets state-wide standards and policies. The jurisdiction of the Central Valley Water Board covers over seven million acres of irrigated agricultural land (Wadhwani, 2018[60]). The Central Valley Water Board’s regime comprises:

- The use of **water quality coalitions to act as intermediaries** between growers and the regulator (in this case, the East San Joaquin Water Quality Coalition83);
- **Data transparency requirements** which incentivise growers to participate in the coalitions;84
- A **representative approach** to water quality monitoring (see Box 7.1); and
- Mandated and voluntary use of **digital tools**, including e-reporting and publicly-accessible data repositories,85 **to minimise costs** of data collection and reporting requirements.

82 In this case, the State Water Board adopted precedential components with direction for the programme, but the Regional Water Boards must adopt those requirements into their own orders for the growers in their Regions before the growers must comply with those requirements.


84 “On 22 June 2006 the Central Valley Regional Water Quality Control Board adopted a Conditional Waiver of Waste Discharge Requirements for Discharges from Irrigated Lands for Individual Dischargers, which took effect on 1 July 2006. The waiver for Individual Dischargers, amended order number R5-2006-0054, sets forth the requirements for individual dischargers participating in the Irrigated Lands Regulatory Program. Dischargers enrolled under the Conditional Waiver for individuals must also comply with Monitoring and Reporting Program Order No. R5-2003-0827”. This regime requires Individual Discharges to report directly to the regulator (Central Valley Regional Water Quality Control Board, n.d.[80]).

However, “[t]o take advantage of local knowledge and resources, leverage limited regulatory resources, and minimise costs, the Central Valley Water Board allowed growers to form **discharger coalitions**, with a third-party representative responsible for grower outreach and education and for implementation of a number of the requirements of the regulatory programme, including representative monitoring” (State Water Board, 2018, p. 21[57]) (emphasis added)

85 The Eastern San Joaquin Agricultural General WDRs require entry of surface water quality data collected under the General WDRs into CEDEN and groundwater quality data collected into GeoTracker. CEDEN is the State Water Board's data system for surface water quality in California. GeoTracker is a statewide database and geographic information system that provides online access to environmental data. (State Water Board, 2018, p. 21[57])
Box 7.1 The representative approach to water quality monitoring in Eastern San Joaquin

The Eastern San Joaquin Agricultural General WDRs do not require water quality monitoring of discharges coming off the farms, but require monitoring in the receiving waters. The watershed is divided into six zones. Two “core” sites and several “represented” sites are designated in each zone. According to the General WDRs, the represented sites are sites with characteristics similar to the core sites such that a water quality issue detected at the core site may be an indication of a similar issue at a represented site. The two core sites are continuously monitored on an alternating basis. An exceedance at a core site triggers the requirement to monitor at the represented sites within the same zone…

[The State Water Board] presented the question of the appropriate surface water quality monitoring framework to the Agricultural Expert Panel. The Agricultural Expert Panel agreed [in its final report, released in 2014] that monitoring of surface water discharges from individual fields or farms is costly and complicated, as well as subject to serious challenges in identifying the appropriate timing for periodic sampling and coordinating with shifting field crew operations, pesticide applications, and sediment runoff events, and with schedules for lab operations…[The State Water Board] continue[s] to believe that receiving water monitoring is generally preferable to field-specific surface water discharge monitoring in irrigated lands regulatory programmes for the reasons articulated by us in Order WQ-2013-0101 and by the Agricultural Expert Panel. Receiving water monitoring is a reliable and effective methodology for identifying water quality issues without resorting to more costly end-of-field measurements.

Source: State Water Board (2018, pp. 53-57[57]).

Recent review of monitoring and reporting regime

In February 2018, the State Water Board adopted Order WQ 2018-0002, which amends and updates the Waste Discharge Requirements (WDRs) General Order No. R5-2012-0116, the WDR for growers within the Eastern San Joaquin River Watershed that are Members of a Third-Party Group. The final Order was the result of an extensive consultation process that commenced with the release of a first draft for consultation in February 2016.

Order WQ 2018-0002 “directs a number of revisions, primarily to add greater specificity and transparency in reporting of management practice implementation, to require reporting of certain nitrogen application-related data needed for management of excess nitrogen use, and to expand the surface water and groundwater quality monitoring programmes of the General WDRs (State Water Board, 2018, p. 1[57]).

The review process covered many complex and specific concerns raised by stakeholders and State Water Board staff. However, at the heart of the review is the broad question whether the existing regime strikes the appropriate balance between providing sufficient data to evaluate the ILRP and ensuring that the burden of monitoring regime for growers satisfies the test of bearing a reasonable relationship to the need for and benefit of monitoring.

In theory, various institutional, legal or technological factors could contribute to a decision to change the existing regime, for example:

- Evaluation of existing data provided by monitoring may lead to the conclusion that the existing monitoring regime is inadequate in some respect(s), thereby
motivating change to ensure provision of sufficient information to effectively evaluate the programme;

- Changes in the cost of the monitoring regime due to technological innovation (e.g. lower cost water quality sensors, new digital technologies for recording, sharing or analysing data) could reduce the regulatory burden of monitoring for growers, leading to a re-balancing of monitoring requirements;
- Methodological innovations (i.e. innovation in approaches to measuring nitrate losses from agriculture) could lead to a change in the monitoring approach towards using new and improved methods;
- Evaluation of the existing third party-based mechanism may reveal unintended consequences which need to be addressed.

In practice, all four of the above factors are present in the State Water Board’s explanation of the changes embodied in Order WQ 2018-0002, albeit in differing degrees.

Methodological innovation was perhaps the most important factor underpinning changes directed in the Order. In particular, the Order implements a recommendation from the Agriculture Expert Panel (see Box 7.1) to introduce a new indicator for monitoring potential nitrate impacts from agriculture: the AR metric (see Box 7.2). This metric is considered scientifically robust and less prone to misinterpretation; both key factors underpinning the decision to require de-identified field-level reporting of AR data.

In response to concerns expressed by some stakeholders (the “Environmental Petitioners”) that the existing monitoring regime is inadequate, the State Water Board directed several revisions to data reporting requirements, in particular:

- To require more granular, anonymous field-level reporting of growers’ land management practices and nitrogen application (related to the AR metric) to the Central Valley Water Board.
- Expansion of the requirements currently imposed only on Members in high vulnerability groundwater areas on all Members, with some limited exceptions.

86 The environmental petitioners considered that the existing regime is deficient in two respects: (i) “there is insufficient disclosure and transparency with regard to the management practices being implemented on the ground by the Members [growers] because only limited, aggregated data must be reported regarding such practices”; and (ii) “the representative and regional monitoring programme does not produce specific enough data to determine if any of the implemented management practices are in fact leading to meeting water quality requirements”. (State Water Board, 2018, p. 22[57])
Box 7.2 The AR metric

Wadhwani (2018, pp. 245, 249-251[60]) provides an overview of the AR metric and its anticipated benefits:

A comparison of the nitrogen-applied [A] with the nitrogen-removed [R] for each field provides a reasonable estimate, even if not precise indicator, of the nitrogen left in the soil that has the potential to percolate to groundwater in the form of nitrates. Minimizing that difference—which can be measured as a ratio (nitrogen applied over nitrogen removed or A/R) or a subtraction (nitrogen applied minus nitrogen removed or A-R)—also minimises the nitrogen left in the soil and consequently the nitrate that may reach drinking water…The A/R and A-R metrics [are referred to] collectively as the “AR metric” and the underlying data as the “AR data”…

The AR metric is an indicator of the amount of nitrogen in the soil that could potentially reach groundwater as nitrate. Over the next several years, as the regional water boards gather the field-level AR data, the data will be analysed to determine ranges of the AR metric for each crop that represent acceptable values to support crop growth, but minimise nitrogen left in the soil. The AR metric ranges will be crop-specific and measured over multiple crop cycles and may be further refined over time for different conditions such as irrigation methods and soil types. Given the challenges of groundwater quality monitoring for evaluating the effectiveness of nitrogen application practices, development of the AR metric ranges currently represents the most promising methodology for fair and even-handed evaluation of efforts to minimise the potential for nitrates to reach groundwater. Significantly, development of the AR metric ranges requires access to the database of field-level data, including field-level values for nitrogen applied, nitrogen removed, and crop type, but not the names and locations associated with that data…

…While AR metric ranges must be based on several years of data, the field-level AR data also supports immediate efforts to reduce the potential for nitrates to reach groundwater. Each grower will have information on how his/her nitrogen application compares to other growers planting the same crops. For any given year, the regional water boards will be able to work with the coalition to identify a set of outliers for each crop and require the coalition (which will have identifying grower name and location information for each field) to follow up with those growers…

… With the requirement for submission of field-level AR data, the Agricultural Order also ensures that…township-level analyses will be fortified by the ability of the more granular field-level data to identify and address over-application of nitrogen in “hot spots” that might otherwise be obfuscated by the averaging effect of township-level data.

Ultimately, the availability of field-level AR data means that the regulatory agencies, research institutions, growers, and public can begin to evaluate what levels of nitrogen application are compatible with safe drinking water and translate that knowledge into improved management practices for particular growers or categories of growers.
in the relevant literature that the cost of wireless water quality sensor networks has declined sufficiently in recent years to make monitoring water quality on-farm a potentially feasible option (or, at least, for high-density network of nodes throughout a catchment—see, for example (Ruiz-Garcia et al., 2009[61]; Zia et al., 2013[62])); at least in this context this does not yet appear to be the case. Nevertheless, the State Water Board directed the Central Valley Water Board to “implement a public external expert review process to evaluate the existing monitoring and assessment framework and make recommendations for improvements or corrections if needed”. This evaluation could explore whether the changes in the costs of different monitoring approaches due to technological innovation are or foreseeably will be sufficient to motivate a shift away from the representative monitoring approach in future; however, given the introduction of the A/R metric as the key indicator for potential nitrate impacts from particular fields, it seems unlikely that a shift towards use of on-farm wireless water quality sensors is imminent.

As stated previously, the State Water Board continues to support the third party (coalition-based) approach. However, it recognises that “concerns with privacy and protection of proprietary information may create strong incentives in support of a framework where the third party retains most information on farm-level management practice and water quality performance rather than submitting that information to the regional water board and, by extension, making it available to the public” (State Water Board, 2018, p. 21[57]). This finding suggests several possible unintended or undesirable consequences of supporting the third party mechanism. First, this support could be seen as legitimising the view that growers have some kind of “right” to confidentiality. Second, the third party may encounter a conflict of interest in that, on the one hand, it needs to report “sufficient” detail to the regulator (which may include farm-level data and even potentially data which identifies individuals), but on the other hand, its members favour reporting of aggregated data only. While the State Water Board has been careful to clarify that it does not recognise any right to privacy in relation to field level data, grower submissions during the consultation process cited an expectation of confidentiality for growers participating in coalitions (Agricultural Council of California et al., 2017[63]), and thus the regulator needs to be continually attentive to these issues and ensure that there is appropriate regulatory oversight of the third party.

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87 For example, Ruiz-Garcia et al (2009[61]) state that Wireless Sensor Networks have “become an important issue in environmental monitoring. The relatively low cost of the devices allow the installation of a dense population of nodes that can adequately represent the variability present in the environment.”

88 The Order states “[t]o the extent we recognise the incentive privacy provides growers to join coalitions, nothing in this order should be construed as recognizing any right to privacy of the specific field-level data and regional water boards retain flexibility provided by this order.” (State Water Board, 2018, p. 22[57]). The State Water Board also stated that “we believe and emphasise that third parties serve an extensive set of functions for growers beyond the maintenance of confidentiality, and we are not persuaded that the maintenance of confidentiality, in and of itself, is a legitimate goal of a regulatory programme that must have transparency and accountability to the public” (State Water Board, 2018, p. 47[57]).
Lessons learned

Lesson 1: Well-constructed data transparency requirements can provide incentive for farmers to participate in collective mechanisms to improve water quality.

In the case study context, if growers do not opt to join a coalition, individual data reporting requirements apply. Thus, this regulatory mechanism leverages growers’ preferences to maintain privacy to incentivise participation in collective governance mechanisms (in this case, the coalitions). This incentive can be reinforced by the use of digital tools customised for the coalition’s use to further lower the transaction costs of reporting data via the coalition. However, regulators seeking to use this approach need to be mindful of (perhaps tacitly or inadvertently) supporting or creating expectations of maintaining confidentiality of farm-level data. Regulators should make clear the circumstances under which anonymised and identified farm level or individual data will be reported to the regulator or made available to the public, and provide for adequate regulatory oversight of the collective entity.

Lesson 2: Digital tools are only one part of a broader approach, and the approach shapes which digital tools are needed.

This case study makes clear that data reporting and transparency requirements are the main tool via which compliance with legal requirements, and programme evaluation, are undertaken. However, the fact that data is required to be reported in digital format and (in some cases) using digital tools such as geographic information systems (GIS) means that digital technologies actually underpin the data reporting system. The choice of the representative monitoring system by the State Water Board, together with the new A/R requirements, influence which types of digital tools are needed: in particular, this system relies on digital platforms into which data is entered manually by Coalition employees or is gathered automatically from Coalition administrative systems, and from which data can be made publicly available. There is less focus on the use of digital technologies to gather primary data (see also Lesson 3).

Lesson 3: Even with the declining cost of sensors, the “representative monitoring” approach is currently considered the most cost-effective.

As noted above, throughout the review process the State Water Board continued to support the representative monitoring approach in favour of what it considers to be a prohibitively costly on-farm monitoring alternative. It remains to be seen whether, during the independent evaluation of the monitoring system, innovative technologies such as low cost wireless sensor networks are considered to be a cost-effective option in this context. While the introduction of the AR metric may preclude demand for use of digital technologies to estimate edge-of-farm nutrient loads, digital technologies including remote sensing technologies and ambient water quality sensor networks may yet prove to be worthwhile additions to the monitoring framework.

89 While of course it is possible to design digital tools for individual reporting, the point here is that exploitation of synergies between data reporting rules and use of digital tools can create incentives for individuals to participate in the collective mechanism.
References


Case Study 8: Estonia e-government and the creation of a comprehensive data infrastructure for public services and agriculture policies implementation

Case study objective

The case study objective is to give a practical example of how a government can build data infrastructure for the provision of public services, including the registration and payment of subsidies in the agriculture sector. The case of Estonia is of particular interest as 99% of their public services are accessible online via a one-time login gateway.

Review of the e-Estonia initiative and its use for agriculture policy implementation

The following is based on interviews with Oliver Väärtnõu, CEO of Cybernetica, a private company which has been developing the data infrastructure for the Estonian Government, and Mr Ahti Bleive, Deputy Director, Estonian Agricultural Registers and Information Board (ARIB – Estonian Paying Agency) Estonia, and responsible for the project SATIKAS that will enable to verify whether the grasslands have been mowed by using satellite data. Along with processing applications for aid, one of ARIB’s duties is to maintain national registers – the register of farm animals and the register of agricultural support and land parcels.

The study has benefited from on-line information about the e-Estonia initiative.90

The creation of a digital infrastructure in Estonia

The development of the Estonian e-Government is based on the Principles of the Estonian Information Policy, adopted by the Estonian Parliament in 1998. Through this, the government initiated a digital transformation to increase efficiency of its processes as well as how efficiently it delivers public services. In addition to a full coverage for digital mobile phone networks in the country91 and ensuring a secure data exchange environment, the Estonian government made two critical technology choices, which supported this digital transformation and referred to as interoperability enablers.

The first was the choice to create, early on, a digital identity (ID-card). This ID-card was made compulsory and was considered as a way to recognise individuals in the digital world, being the key allowing the real world to match the digital. The card is issued by the government and was made a mandatory document. The adoption was also facilitated by Estonian banks, which heavily invested in e-Banking and were using the e-ID card as a way to access their services. The system is based on cryptographic keys, with a personal key, which used as the primary key in the majority of databases containing personal information. In particular, it can be used in the public key infrastructure (PKI), for authentication and signatures identification. The state undertakes to assure the existence and functioning of the public key infrastructure.

91 100% advanced 3G mobile broadband coverage.
The Police and Border Guard Board is issuing personal (digital) identity documents enabling secure electronic authentication and digital signing (ID-card or another smart card).

- The Ministry of the Interior drafts legislation that determines the types and requirements for the digital identity documents
- The Information System Authority (RIA) develop software applications necessary for using the PKI (ID-card middleware including drivers, utility and client software).
- Ministry of Economic Affairs and Communications (Department of State Information Systems): determines the quality

eID-cards can also be stored on smartphones using a special SIM card enabling the use of a mobile ID. In Estonia, a digital signature has similar juridical power than a written one.

The second choice was to develop the X-Road, the data management infrastructure. In the name of efficiency, data management is often centralised, meaning putting all the data together in a single digital facility. Such option has the advantage to facilitate access to data and to be cheaper. This is the reason why small countries usually decide to adopt such systems. However, it also create vulnerabilities and increases the risks: hackers would only have to attack one facility to access all data, making it a potentially lucrative exercise.

Estonia innovated in choosing a decentralised system. However, such systems are usually confronted to issues of inter-systems connectivity, resulting in duplication of data storage or harvest when sharing is not possible, ultimately resulting in higher costs. To solve and avoid those constraints, the Estonian government innovated, in a decentralised linked government data infrastructure, the XRoad. To make sure that government bodies would all adopt this strategy, a law was passed stipulating that the same information should not be asked twice. Agencies looking for some information should go directly to the agency holding the data. This access is secured by cryptography and information about the exchanges is referenced.

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92 This is a principle that also applied in the European Commission: the “once only” principle.
Box 8.1 Some figures about costs and benefits of digitalisation in Estonia

Digital transformation is an overarching process. It started in Estonia with first applications early 2000 and Estonia’s administration applies a principle of digital-by-default. It is therefore difficult to extract some distinct comparative figures about the cost benefit of this process. However, a few indicators are available: 99% of Estonia’s public services are online, 98% of Estonian nationals use eID-s, which are used to produce more than 10 million digital signatures per year. The use of the data exchange layer, X-Road, saved Estonian administration 804 working years compared to previous calendar years and it is estimated that using the electronic signature saves 2% of the Estonian GDP each year. ICT sector forms about 7% of Estonia’s GDP.

On the cost side, Estonia spends approximately 1.1% to 1.3% of the state budget on digitalisation. The actual need are around 1.5%. In comparison, the same number in Finland is 1.4% but in Denmark 2.4%.

Source: https://www.x-tee.ee/factsheets/EE/#eng

The proof of concept was tested in 2004 and then they started building the ecosystem. The first application was internet voting in 2005. The uptake slowly increased. In 2015, 19.6% of the eligible voters voted on-line, representing 30.5% of the participating voters. In March 2019, the numbers were 27.9% and 43.9%, respectively. Also, votes can now be made from anywhere in the world. In 2015, votes were received from 116 countries. In 2019 it reached 143 countries.

Application in the case of Agriculture policy and regulations

The Estonian paying agency has been using satellite imaging and remote sensing since 2005. Controls were then increasingly automated from 2011, before Sentinel data arrived and provided more detailed images. Access to data from Sentinel allowed further automation of processes. Automation of processes is mostly for mowing requirements, specifying that mowing has occurred before or after certain dates. While more flexibility might be provided to this requirement to match environmental realities better (see case study on meadow birds’ supervision) mowing data is a requirement that is often violated. Accordingly to EC requirements EU wide, only 5% of fields are physically checked on site by controllers. With remote sensing and automation of processes, this percentage reaches 100%, meaning that all the monitoring can now be done remotely, by detecting the changes in biomass. Information is based on GIS data, entered by the farmers and checked by the agency availing it to all farmers registered.

Beyond this example a broader range of digital services are now available to farmers, including digital registers. For instance, farmers can provide information about birth of an animal, whether they are moving their pack, etc. In other words, all types of information that previously had to be recorded on paper can now be recorded on line.

Table 8.1 Uptake of the animal register e-services since 2006

<table>
<thead>
<tr>
<th>Year</th>
<th>Documents</th>
<th></th>
<th>Events</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>% E-service</td>
<td>% Paper based</td>
<td>% E-service</td>
<td>% Paper based</td>
</tr>
<tr>
<td>2006</td>
<td>0.42</td>
<td>99.58</td>
<td>2.37</td>
<td>97.63</td>
</tr>
<tr>
<td>2007</td>
<td>7.00</td>
<td>93.00</td>
<td>19.23</td>
<td>80.77</td>
</tr>
<tr>
<td>2008</td>
<td>13.50</td>
<td>86.50</td>
<td>31.13</td>
<td>68.87</td>
</tr>
<tr>
<td>2009</td>
<td>21.36</td>
<td>78.64</td>
<td>42.03</td>
<td>57.97</td>
</tr>
<tr>
<td>2010</td>
<td>28.53</td>
<td>71.47</td>
<td>53.17</td>
<td>46.83</td>
</tr>
<tr>
<td>2011</td>
<td>36.10</td>
<td>63.90</td>
<td>60.74</td>
<td>39.26</td>
</tr>
<tr>
<td>2012</td>
<td>40.96</td>
<td>59.04</td>
<td>66.74</td>
<td>33.26</td>
</tr>
<tr>
<td>2013</td>
<td>44.52</td>
<td>55.48</td>
<td>69.39</td>
<td>30.61</td>
</tr>
<tr>
<td>2014</td>
<td>48.40</td>
<td>51.60</td>
<td>73.29</td>
<td>26.71</td>
</tr>
<tr>
<td>2015</td>
<td>51.74</td>
<td>48.26</td>
<td>76.85</td>
<td>23.15</td>
</tr>
<tr>
<td>2016</td>
<td>55.44</td>
<td>44.56</td>
<td>80.60</td>
<td>19.40</td>
</tr>
<tr>
<td>2017</td>
<td>60.36</td>
<td>39.64</td>
<td>85.68</td>
<td>14.32</td>
</tr>
<tr>
<td>(12.08.) 2018</td>
<td>64.35</td>
<td>35.65</td>
<td>88.85</td>
<td>11.15</td>
</tr>
</tbody>
</table>

Note: Documents can be birth or veterinary certificates. Events can be the movement of the pack to another location etc. 
Source: Communication from the Estonian Agricultural Registers and Information Board.

In order to support the shift from paper to digital, the government launched different advertising campaigns to communicate its advantages to farmers, including a more rapid identification and treatment of errors. Advice services explaining how to fill documents online are free and was very welcomed by farmers. The system relieved farmers from some administrative burden and from the potential time previously needed to rectify errors in the documentation when occurring. In addition, as administrative processes are managed faster, payments are more rapidly transferred to farmers.

The LPIS (land parcel identification system) and animal data are also used by statistical offices and for the cadastre system as well as by the environment agency, allowing conducting cross checks with different agencies. For example, in the case of investment measures, it is possible to check whether the applicant is in debt or has taxation problems. In general, this system is well accepted as most of the time, its purpose is to provide support.

In the case of the environment ministry, the administration can get access to useful information on livestock systems, and in particular on manure.

Ministry of Rural Affairs has initiated a feasibility study for development of agricultural big data system. The aim is to create a central electronic system to link and integrate existing data with analytical models and practical applications. Data linked in this system must be harmonised, compatible, updated, linked to spatial data, transferable from the producer to the system and from the system to the producer enabling access to potential models/applications.

The system will provide useful practical information flow for the farm management decisions (e.g. machine-readable data for the precision farming machinery). The system will also enable to collect more precise farm data with less effort. This improves the quality of statistical data and enables more comprehensive analyses.
The study includes the assessment of the needs and roles of stakeholders, assessment of data storage systems and evaluation of existing data quality. The proposed concept of the big data system will include the technical, legal and economical analyse and the roadmap for implementation of such system. The project includes trainings for the farmers to explain the potential of the use of big data for farm management decisions, to introduce the practical applications and models for that purpose and to demonstrate the technologies for precision farming.

This one-year duration project started in September 2018. The next phase will be the implementation of the system based on the results of the feasibility study.

**Lessons learned from the development of a government data infrastructure and use in agriculture**

Efficiency gains for both citizens and the government is the objective of the digitalisation of government services in Estonia. This infrastructure was not implemented in a piece meal manner, and rather was built as a comprehensive, open but secured and flexible way. The lessons learned in this case study are more about the questioning and elements to consider when creating such infrastructure. The implementation was successful, but was nevertheless confronted to challenges, which can serve as learning material for other OECD countries.

**Lesson 1: The implementation of Estonia data infrastructure required the government to rethink the way it was operating, as well as its role and what problems the previous government administration organisation was facing.**

One of the first questions was about the way to create interoperability between government agencies, previously operating in silos and with their own system. It was important to ensure the protection of government data and who had access to it. Estonia dealt with such problems using a decentralised system and cryptography, but also by using the blockchain. All information about any request for information is registered on the blockchain and citizens are able to check who, and when, accesses their data.

The other question was how to make government data more useful to citizens and in the case explored here, to farmers. If the role of the government is to gather relevant information for the use of policy implementation, is it also the role of the government to expand their database to information that is not directly of use to the government but can be for farmers when combined with government data? Enabling private sector access to government data brings the questions of data ownership. However, in practice, the question is more about data use and what data will be used for then about data ownership. It is envisaged that in Estonia, the data management system could be based on an agreement per data type by farmers. The data infrastructure created by Estonia, clearly identifying who accessed data could enable the creation of such system.

**Lesson 2: The creation of a data infrastructure requires creating a setting and a regulatory environment guaranteeing trust in the new system.**

Data security is taken very seriously in Estonia and is considered to be the most important feature allowing the Estonian digital society to function. Anyone with a social security code can look up their information online, see who has accessed their data and when. It is also possible to ask about any single query, which allows for a higher trust in the services. The rare occurrence of data privacy violation have been treated as important offences to serve as a deterrent.
Legislation including a range of acts created the core principles of the development of the Estonian e-government. Some were adopted by the Estonian parliament as early as in 1998, then reviewed and updated in 2006 in the course of preparing the Estonian Information Society Strategy 2013.

- Digital Signatures Act
- Archives Act
- Population Register Act
- Identity Documents Act
- Personal Data Protection Act
- Information Society Services Act
- Electronic Communications Act
- Public Procurement Act
- State Secrets and Foreign Classified Information Act

One of core principles is that the public sector is leading the way for the development of what is more broadly referred to as the information society, but developments are in cooperation between the public, private and third sector. Therefore, and in order to reassure the Estonian society about the use of their data, a range of acts have been pasted to ensure the protection of fundamental freedoms and rights, personal data and identity. In particular, individuals are the owners of their personal data and they have an opportunity to control how their personal data are used.

Lesson 3: Providing the right incentives with flexibility to implement change and avoid barriers to adoption, both within the government and between the government and citizens.

In Estonia, the regulatory environment has been used to set the incentive for the implementation and use of the e-government by government agencies, by centralising policy development, letting the Ministry of Economic Affairs and Communication develop the principles of information policies and supportive legislation, also taking responsibility for supervision of relevant state organisations starting from 1993. Then the implementation was decentralised, with e-Government developments done mainly by responsible ministries and state agencies. Accordingly, every government department, ministry or business, gets to choose its own technology, based on commonly agreed principles.

It appears that in the case of Estonia, there has been little barriers to adoption, whether from the institutional side or from the users’. Various reasons explain this, including the population size making implementation more straightforward and communication about initiatives more efficient. On the agriculture side, the fact that data provided by farmers is used to provide support, and not only, like in other countries, to verify that the farmers complies with regulations, had an important role in the level of adoption. But so did the support to farmers in getting to know the platforms and the additional on-line services compared to paper based communication (revision of documents, etc.) provided by government bodies.

References


Case study 9: Connecting the dots to create a data infrastructure: the US National Soil Moisture Network

Case Study objective

The objective of this case study is to provide the example of the National Soil Moisture Network (NSMN) initiative in the United-States, which intends to address the fragmentation and heterogeneity of data coverage for the tracking of soil moisture. Its intent is to combine data from satellites with the data captured from state level in situ networks, to build a national inventory that can inform policy management and decisions.

Context: disconnect between different layers of data about soil moisture in the United States prevents their reuse for comprehensive water policies.

Soil moisture matters to inform policy makers.

Soil moisture is an important element for the assessment of water use and water demand. Soil moisture data are critical for assessing:

- Drought conditions and operational drought monitoring
- Flood forecasting
- Land surface modelling (Component in weather and climate models, to simulate the exchange of surface water and energy fluxes at the soil–atmosphere interface.)
- Crop yield estimation
- Water supply forecasting
- Operational hydrologic models
- Weather forecasting

Mesoscale in situ meteorological observations provide the data used for weather and climate forecasting and decision-making. The data they create are essential to a large range of stakeholder communities. These include state environmental and emergency management agencies, water managers, farmers, energy producers and distributors, the transportation sector, the commercial sector, media, and the general public (Mahmood et al., 2016).

The history of the development of soil monitoring in the United States.

Two types of technologies are used for the monitoring of soils water content in the United States. The first system relies on direct in situ instruments; the second relies on remote sensing. Each approach has strengths and weaknesses, and each was designed and has evolved to meet specific purposes and goals.

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94 Roughly spanning a 30 km radius or grid box around a given location
The in-situ monitoring of surface soil moisture in the United States is not new. The first surface weather observations began on the East Coast in the late seventeenth century (Fiebrich, 2009). Those sparse initiatives were then organised into a network of volunteer weather observers by the Smithsonian Institution, following the Surgeon General, army, and General Land Office request for regular observations at widespread locations. From the 1970s, technological improvement allowed the process of automation of weather data collection with the development of sensors and multiple-function data processors at remote sites. Cellular and satellite communication systems also allowed for a more rapid transfer of information. Developments ultimately lead to the creation of automated weather networks, continuously providing data, such as soil moisture and temperature enabling near-real-time decisions. Those systems rely on sensors which provide instantaneous estimates of soil moisture at discrete depths, but also can provide event detection, event ID, location sensing, and local control of actuators (device responding to a digital signal, for instance a valve in an irrigation system). As technology continues to progress, the concept of micro-sensing and wireless connection of these nodes promise many new application areas, including the monitoring of environmental conditions and precision agriculture.

Most data used by researchers are still mostly at the 30 km scale. Those mesoscale networks, also called mesonets, were principally resulting from initiatives at the State level. Their coverage across the United States is different in intensity, but also in nature and were developed for specific diverse purposes. In addition, some of those networks operate on a fee basis to fund themselves in part or in whole.

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95 The foundation for today’s National Weather Service Cooperative Observing Program (COOP).
Table 9.1 Statewide mesonet

<table>
<thead>
<tr>
<th>State</th>
<th>Network</th>
<th>Total number of real-time stations</th>
</tr>
</thead>
<tbody>
<tr>
<td>Alabama</td>
<td>North Alabama Climate Network</td>
<td>22</td>
</tr>
<tr>
<td>Alabama</td>
<td>University of South Alabama Mesonet (CHILI)</td>
<td>25</td>
</tr>
<tr>
<td>Arizona</td>
<td>Arizona Meteorological Network</td>
<td>21</td>
</tr>
<tr>
<td>Arkansas</td>
<td>Arkansas State Plant Board Weather Network</td>
<td>50</td>
</tr>
<tr>
<td>California</td>
<td>California Irrigation Management Information System</td>
<td>152</td>
</tr>
<tr>
<td>Colorado</td>
<td>Colorado Agricultural Meteorological Network</td>
<td>75</td>
</tr>
<tr>
<td>Delaware</td>
<td>Delaware Environmental Observing System</td>
<td>57</td>
</tr>
<tr>
<td>Florida</td>
<td>Florida Automated Weather Network</td>
<td>42</td>
</tr>
<tr>
<td>Georgia</td>
<td>Georgia Automated Weather Network</td>
<td>82</td>
</tr>
<tr>
<td>Illinois</td>
<td>Illinois Climate Network</td>
<td>19</td>
</tr>
<tr>
<td>Iowa</td>
<td>Iowa Environmental Mesonet</td>
<td>17</td>
</tr>
<tr>
<td>Kansas</td>
<td>Kansas Mesonet</td>
<td>51</td>
</tr>
<tr>
<td>Kentucky</td>
<td>Kentucky Mesonet</td>
<td>66</td>
</tr>
<tr>
<td>Louisiana</td>
<td>Louisiana Agroclimatic Information System</td>
<td>9</td>
</tr>
<tr>
<td>Michigan</td>
<td>Enviroweather</td>
<td>82</td>
</tr>
<tr>
<td>Minnesota</td>
<td>Minnesota Mesonet</td>
<td>8</td>
</tr>
<tr>
<td>Missouri</td>
<td>Missouri Mesonet</td>
<td>24</td>
</tr>
<tr>
<td>Nebraska</td>
<td>Nebraska Mesonet</td>
<td>68</td>
</tr>
<tr>
<td>New Jersey</td>
<td>New Jersey Weather and Climate Network</td>
<td>61</td>
</tr>
<tr>
<td>New Mexico</td>
<td>New Mexico Climate Network</td>
<td>6</td>
</tr>
<tr>
<td>New York</td>
<td>New York Mesonet</td>
<td>101</td>
</tr>
<tr>
<td>North Carolina</td>
<td>North Carolina ECONet</td>
<td>40</td>
</tr>
<tr>
<td>North Dakota</td>
<td>North Dakota Agricultural Weather Network</td>
<td>90</td>
</tr>
<tr>
<td>Oklahoma</td>
<td>Oklahoma Mesonet</td>
<td>120</td>
</tr>
<tr>
<td>South Dakota</td>
<td>South Dakota Mesonet</td>
<td>25</td>
</tr>
<tr>
<td>Texas</td>
<td>West Texas Mesonet</td>
<td>98</td>
</tr>
<tr>
<td>Utah</td>
<td>Utah Agricultural Weather Network</td>
<td>32</td>
</tr>
<tr>
<td>Washington</td>
<td>Washington AgWeatherNet</td>
<td>176</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>1619</strong></td>
</tr>
</tbody>
</table>


While those networks are useful for some of applications, the understanding of a range of natural phenomenon requires a broader coverage, national if not beyond borders. In addition, the understanding of the dynamics of soil moisture requires more information than soil moisture data point estimates. It requires knowledge about soil characteristics, not only surface composition, but also composition across multiple soil depths, weather patterns, and land use information. These data layers are available but in disparate data networks and from different sources.

More recently, capacities have increased, in particular in the context of the development of new data storage, processing and aggregation capacities (big data). Today, sensors networks are more than networks creating data. Their use relies on algorithms and communication protocols. Data layers captured by sensors networks are compiled with other data to make predictions and support decision making of a range of stakeholders, from farmers to policy makers. For example, a range of environmental conditions, including information about soil moisture and nutrients, can be combined by an algorithm to estimate crop health and production quality over time. The more precise networks, such as wireless sensors networks (WSN), providing data at the farm level, can be integrated into decision systems for precision agriculture or water management. For example, a sensor
can measure levels of humidity and be linked to an actuator responsible for opening an irrigation valve.

The other technology available is remote sensing, which presents the advantage of allowing contiguous data coverage across the United States.

The use of digital technologies to improve the coordination and use of soil moisture data.

**The problem**

While a large amount of data exists and could support researchers and policy makers, it is not used to its full potential.

Sensors networks developed at the farm level are the only one providing information at a level of granularity fine enough for farmers to use for decision making, analysis and monitoring of soil moisture on farm. However, those are often private and systems are proprietary. In addition, the data is considered\(^{96}\) as belonging to either the farmers or the company providing the service and therefore not easily accessible by other stakeholders, including researchers and the government.\(^{97}\)

At the level of mesonets (States), many in-situ sensors networks have been developed in the United States, but they are distributed unevenly, with some geographic areas being more densely covered than others. In addition, they are not always publically accessible and protected by paywalls. Finally, remote sensing data is gaining in popularity now that multiple high quality platforms are providing near daily products. However, data provided is still at a coarse resolution. Models can also be used to provide better spatial coverage, but they are limited by input data layers (primarily precipitation) and have water budget closure issues. Indeed, many factors influence how soil moisture varies, including soil properties, topography, vegetation, land cover or land use and climate.

The production of an accurate representation of soil moisture at an informative scale enabling policy management and monitoring and with regular coverage and comparative data on conterminous United States the 48 adjoining States plus Washington, D.C. on the continent of North America (CONUS) has been a challenge. This was the result of a lack of technical capacity (data processing and management) but also of the existence of parallel independent and non-coordinated developments of networks across the United States. Consequently, soil moisture observations have been poorly integrated into assessments of vulnerability, for instance early warning systems for droughts and floods.

The central issue is the traditional investment behaviour conflicts in infrastructure in networks industries (fixed networks to deliver services based on lumpy initial investments and presenting elements of natural monopoly), which calls for role of the public sector as a provider of public services. In the case of the United States, this is also a problem linked to devolution and differences in investment priorities among States. The realisation of this issue and of the opportunity cost of the lack of coordination for policy management

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\(^{96}\) See section discussing data ownership and the example of the Privacy and Security Principles for Farm Data in the United States in main report.

\(^{97}\) See main report for a discussion about data ownership. In the United-States, farmers are reluctant to share data about their production system.
triggered an effort to promote the better integration of soil moisture data across the United States, spawning the National Soil Moisture Network (NSMN) initiative.

**Overview of the National Soil Moisture Network (NSMN) initiative**

In 2013, the National Integrated Drought Information System (NIDIS) initiated discussion for the development of a Coordinated National Soil Moisture Network. This network is intended to be based on Federal and State in situ monitoring networks, satellite remote sensing missions, and numerical modelling and draw on the experiences of the soil moisture community. Such a platform would aim to improve knowledge of soil moisture status across multiple spatial and temporal scales and over multiple soil depths.

The initiative brought together experts from the USDA Natural Resources Conservation Service’s Soil Climate Analysis Network (SCAN) and Snow Telemetry (SNOTEL) in situ instrument networks (Schaefer et al., 2007); the NOAA Climate Reference Network (Diamond et al., 2013); state in-situ networks; remote sensing and modelling experts from NASA, NOAA, and USDA; and soil moisture database managers from academia and federal and state governments.

The first workshop held in 2013 highlighted a range of issues in relation to soil moisture data. At the conclusion of the workshop launching the initiative (McNutt, Verdin and Darby, 2013), the need was identified for improving metadata and calibration and validation of soil moisture data as well as data integration, leading to the creation of the initiative for the development of the National Soil Moisture Network (NSMN). The original objective was to develop a high-resolution gridded soil moisture resource, accessible to the public through a web portal. Therefore, the project brought together in situ measurements of soil moisture from the federal networks, in combination with a range of other databases, including the NRCS SSURGO, which provides a unique gridded database of soil properties and satellite (PRISM) data.

As a result of the first workshop, NIDIS funded a pilot project operated by the North American Soil Moisture Database at Texas A&M University, focusing on the southern plains networks of the U.S. to demonstrate the feasibility of the process. Challenges included data transfer protocols, storage, and data gaps from intermittent connectivity to stations.

Additional NSMN workshops were held in 2016, 2017 and 2018, with the last meeting held in Lincoln Nebraska at the National Drought Mitigation Center. As a result of this workshop, an Executive Committee was formed and a charter was drafted to provide more structure to the effort.

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98 Information about the development of the NSMN was taken from sources available on the website of the National Integrated Drought Information System.

Rationale and lessons learned from the development of a National Soil Moisture Network

According to the type of public services required, to the institutional environment and initial conditions of the network, enabling the development of a data infrastructure might require different types of actions and role for the government, whether as a central planner, as a regulator setting interoperability standards or to directly develop the data infrastructure and create markets for usage rights. The role of the government is likely to change according to how advanced those networks are, whether the service provided can be marketable and whether the costs of providing the services are higher than the benefits.

Lesson 1: there is path dependency from previous policy-making and infrastructure development on the data infrastructure and governance.

In the case of the NSMN, issues result from path dependency from the devolution of investments decisions to sub-national scales, investments that were taken rationally according to priorities in each particular State. While there was a logic in this devolution, today, this lack of coordination and alignment of objectives creates inefficiencies in terms of data creation, management, potentially spiralling down into poor water policies and managements in a context of information gap.

A lot of data is already being produced which could be better exploited by cutting across administrative borders. A maintenance updating of the current mesonet infrastructure and the creation of an enabling environment for data sharing might be enough for the creation of an efficient data infrastructure. Both the public and private sectors – Farmers, policy makers and the community – would benefit from better preparation and resilience to drought.

The NSMN initiative acted as a catalyst, bringing together institutions and creating awareness about the specificity of soil moisture monitoring, highly variable in space, depth and time.

Lesson 2: There could be a role for the government to support the development of infrastructure.

A traditional question for network infrastructure is where the role of government stops and where the role of private sector starts. There might be cases requiring broader government support to the financing of network infrastructure, including in less economically important areas.

In addition, questions about the sharing of data according to the status, definition and value (economic and social) provided to the different users of data produced by private systems is still to be discussed. Discussions at the Global Forum for Agriculture held at the OECD in May 2018 highlighted a range of diverging views in relation to data ownership, and the issue of privacy. In particular, asking the question of which types of information and

99 Or worldwide but this would go further than the premises of this document which is focusing on domestic policies. Initiatives at the G20 are aiming to develop such knowledge sharing international networks. See G20 Meeting of Agriculture Ministers declaration, 27-28 July 2018, Buenos Aires, Argentina: “We highlight the importance of enhancing the quantity and quality of soil data and information and support the sharing of knowledge and technology to measure, restore, rejuvenate and maintain soil health.”

100 Although cost-benefit analysis are often difficult to implement for issues in relation to the environment and disaster risk reduction.
derived conclusions can be left with the private sector and which need to be managed (governed) by public authorities.

The NSMN is in the process of using existing networks, but most current networks were created with spatially restricted objectives (states, watersheds, etc.) and the concluding report of the workshop, which launched the creation of the NSMN in 2013 (see McNutt et al., 2013) mentioned that an increase in the number of monitoring sites would be the most important improvement in the overall depiction of soil moisture. Indeed, drought risk and water flows do not end at regional borders nor are they only an issue within one land cover group, and more specifically highly productive areas: water management, policies and drought risk require a comprehensive understanding of soil water dynamics at a high resolution across all landscapes.

To be considered too is that new sources of data will likely become available in the future with the digital transformation of agriculture. Although the sharing of data between stakeholders is not a given, the private sector might have incentives to develop infrastructure when it holds promises of profitability. For instance, WSN can be developed to support decision systems, more likely to be sold to farmers. Consequently, WSN would produce a lot of information, in specific areas, such as high density farming areas, to which services can be provided to make investment profitable. However, there might still be constraints to the sharing of such data. In addition, the quality and veracity of data obtained via private application of new digital technologies to support policy-making would need to be ensured.

Finally, the creation of a network of sensors and of information needed to monitor soil moisture in ways that allow the provision of public services such as drought early warning systems, and to inform water policy and management, requires coverage of all geographic areas, whether cultivated or not. Such cases identify a clear role for the government as it might not be economically viable for the private sector to develop infrastructure in some areas, which are nevertheless important for the understanding of ecosystems dynamics and forecasting. In addition, myopic views of hydrologic concerns have major impacts downstream.

*Lesson 3: there might be a role for some regulatory oversight or central planners when there is a collective gain to coordination but no returns or private incentives.*

This leads to the second issue highlighted by this case study, which is interoperability standards. Any network or platform, whether public or private is developed to answer specific questions, achieve certain purposes, explaining their difference of approach to data creation, management and codification. As a consequence, the data produced might not be “fit for purpose” and create biases if used in modelling and analytics that depart from the initial goals. While there can be collective gains to coordination, there might not necessarily be private or return incentives. In such cases, networks lend themselves to some form of regulatory oversight or a central planner.101

With the creation of the NSMN, an important need was for the data produced to be usable for a diversity of objectives and by a diversity of end users. The first step of the NSMN was the coordination of existing networks, bringing together current entities in a common format. As such, the NSMN also acted as a standards marker: effectively leveraging the

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101 WMO is in the process of developing standards for soil moisture network development.
full variety of existing networks and modelling efforts first relied on consistent calibration and validation practices and metadata characterisation.

References


National Integrated Drought Information System (2013), Developing a Coordinated National Soil Moisture Network Findings from meeting in Kansas City, Missouri, Nov. 13-14, 2013, written by Chad McNutt, NOAA/NIDIS, James Verdin, USG, Lisa Darby, NOAA/NIDIS.

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Case study 10: Data infrastructure and the potential role of the government supporting the data infrastructure – example of the Akkerweb in the Netherlands

Case study objective

The Akkerweb is an open platform for digital services for precision farming. This case study provides a practical example of how public-private partnership on an open data infrastructure can facilitate the creation and uptake of value adding services by the private sector, supporting productivity growth and sustainability improvement in agriculture. As such, the Akkerweb is a new way for the government to support access to advise services to farmers. Akkerweb is a foundation, founded by both Wageningen University and Research and a farmers’ association, Agrifirm.

Context: fostering capacities, good use of public data and support private sector services development in precision agriculture

The problem

Farmers have been using guidance systems, yield monitoring, variable rate application, long-distance transmission of computerised information (telematics) and data management for a long time (OECD, 2016[64]). The use of digital tools on-farm has been developing over time and a farmer can end up having to manage a multitude of unrelated systems giving various information (e.g. about yield variation, production assets characteristics) but rarely connecting the different elements to explore correlations and causations. Most data points make more sense when provided with the context and put in relation with benchmarks, trends, or causal references, applying and testing knowledge obtained from experience, either on farm but also though innovation and research.

One of the key reasons data has not been used to its full potential to date is that farmers often lack the tools and skills to analyse jointly those multiple sources of data and fully exploit them. The inability to link data across systems, each focussed on a specific task, prevented both insights into the relationship between certain management practices and within the farm system, at least in the absence of costly manual data synthesis.103

This fragmentation of data created a data gap that not only prevents its efficient use on-farm, but also its reuse for research and deeper analysis. While on farm, a large amount of data is acquired but cannot be combined to produce knowledge beyond the initial intended purpose; on the research side (relying on some public data such as remote sensing data), data is often only available at in an aggregated form. The use of this data for the production

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102 In precision agriculture, Variable Rate Application (VRA) refers to the application of a material, such that the rate of application is based on the precise location, or qualities of the area that the material is being applied to. Variable Rate Application can be Map Based or Sensor Based.


Unclassified
of knowledge at the level of the individual animal, field or farm is then limited, and, where it does occur, is often costly and cumbersome.

**The Akkerweb brings together public and private data to support precision agriculture.**

*Akkerweb* is an initiative of both Wageningen University and Research (WUR) and farmers’ association Agrifirm. In this joint venture, both scientific knowledge and a practical approach to farmers’ problems is combined. The *Akkerweb* was thought as an open platform for precision farming, enabling to bring all farm data together and in addition, proposing a variety of agriculture related applications usable by farmers, using this data, to support their decision making process in order to optimise their production objectives.

In in particular, WUR currently provides free satellite data, which require specific analytics capacity to interpret and translates them into in vegetation indices. Those vegetation indices are complex mathematical combination or transformation of spectral bands that accentuates the spectral properties (how leaves react to ultraviolet, visible, and infrared frequencies) of green plants so that they appear distinct from other image features. Such indices usually provide indication of the amount of vegetation, meaning the percent cover or the biomass, and they also distinguish between soil and vegetation. The tech start-up Bioscope combines a mix of public and commercial satellite data and drones data to provide a guaranteed data stream essential for precision farming.

This data is them combined with other data from the private sector and farmers, for a range of advice services. Some applications have been built in by the WUR research team, others are added by the private sectors, and require payment.

The platform compiles information made available by farmers in one “geo-platform”, where the geo-spatial location is a key connection between activities, data sets and analyses. For arable farmers a ‘crop rotation application’ is the entry point to explore the data and serves as the foundation for all the functionalities that provide added value to farms operations (e.g. for fertilisation or crop protection).

Farmers can freely open an account and add information that is securely managed: In *Akkerweb*, the farmer can combine his farm specific data with data from public sources (satellites, soil maps, weather data, parcel maps from the Netherlands Enterprise Agency (RVO), etc.), but also proprietary data sources such as sampling bodies (laboratories and certification), other parties in the value chain, farm management systems, own sensors etc. Active links are available with the data store of the national Paying Agency (RVO) and with other farm management systems, to prevent double entry of data. Only the farmer has access to his own data but he can grant access to others on his own discretion. In this way, he can give access to his advisor to help him monitor the crops or interpret a soil analysis.

Farmers are therefore free to share enriched data with advisers and other users on the platform, to obtain practical recommendations\(^\text{104}\) to optimise crop production. The system itself provides interoperability of data. Any data provider can upload their data (e.g. soil laboratories) and make them available to farmers. Different private sector companies have their own “app” on the platform for farmers to use at their discretion. *Akkerweb* is in the first place a digital repository and work bench. Applications are built on top of this data

\(^\text{104}\) Or actionable insights.
repository either by the public or the private sector, ranging from visualisation to analytics and decision support.

It is generally accepted by the user community that farmers are the controllers of their data and the platform was built as GDPR (European Union, General Data Protection Regulation) compliant.

**Lessons learned**

*Lesson 1: To be adopted and successful, digital technologies have to be designed based on expressed user needs.*

Commercial GIS software, in use by many professionals, failed to gain traction in farming because of their price and complexity. The GIS functionality in Akkerweb is designed based on expressed user needs. In that sense, Akkerweb filled a need. Moreover, the ability for third parties to develop applications is a strong advantage over some of the other platforms.

*Lesson 2: The success of the platform relies on the integration of all public and private sector stakeholders of precision agriculture.*

Other technical platforms offer similar technology, but a success of Akkerweb is the strong interaction between stakeholders, which provides both scientific backstopping to models and algorithms, and practical approach concerning functionality. Public bodies are participating in the data repository construction by linking their agriculture policy data (for example LPIS) to the platform as well as supporting the pre-processing of satellite data.

**References**


Annex B. Agri-environmental policy components and policy mechanisms

The policy cycle shown in conceptual framework for analysing use of digital technologies for better agricultural and agri-environmental policies (Figure 2.1 of the main report) is a stylised representation of the broad components undertaken to design, successfully implement, and evaluate an agri-environmental policy. In that figure, the components are set out linearly; it is acknowledged that the particular components and ordering of components for a particular policy will depend on context – the emphasis here is on considering the usefulness of digital technologies for each component. The components, drawn from the literature on agri-environmental policy design (see for example, OECD (2008) and OECD (2010)), are:

- **Policy Design:** identification of policy issues and definition of policy objectives. Specific operational objectives or targets which will achieve the broad objectives are then identified. Having defined the objective(s), the next step is the selection and specification of a particular policy mechanism (or suite of mechanisms) to achieve the objective(s).

- **Initial outreach and enrolment in policy mechanism** is the preliminary step for implementation. It is the process of raising awareness of the policy mechanism with potential participants, soliciting (voluntary) or requiring (regulatory) participation, gathering baseline data and checking eligibility criteria are met (if applicable) and enrolling participants. Depending on mechanism design, this may consist of informing the regulated community of requirements; registering programme participants in a database; gathering baseline information; performing preliminary eligibility checks; setting up a process to accept tenders or auctions, etc.

- **Implementing policy mechanism:** This entails the practical implementation of the policy mechanism. Depending on mechanism choice, this could involve, for example, administering payments provided to eligible farmers; executing contracts; administering tradeable permit programmes, etc.

- **Monitoring and enforcement (if relevant) of participation in policy mechanism** in order to be able to assess whether they are in compliance (examples include: auditing for regulatory compliance in a mandatory scheme; in a voluntary pay-for-practice programme, verifying whether contracted best management practices (BMPs) have been implemented and are being maintained as per the terms of the contract, etc.). Further, if non-compliance is identified, carrying out enforcement protocols (e.g. requiring remedial action, fines, legal action, etc.).

- **Policy evaluation** involves monitoring the achievements of the policy mechanism, relative to its objective (effectiveness) and also in terms of the costs of implementing the policy mechanism (efficiency), including transaction costs.\(^{105}\)

- **Communication with broader public about policy** involves sharing information about the policy mechanism, including progress toward achieving the objectives and the results of evaluations, with the broader public. Further, feedback from interested stakeholders is sought. This 'component' could be performed throughout the policy cycle - e.g. initial consultation during the policy design component;

\(^{105}\) OECD (2010) defines the “environmental effectiveness” of policies as their success (or otherwise) in achieving their stated environmental objectives, and “cost-effectiveness” as the degree to which the policy instrument achieves its objective at minimum cost.
ongoing communication and consultation about implementation progress; participation of stakeholders in policy evaluation, etc.

This report notes that digital technologies are useful for a range of different agri-environmental policy mechanisms. Table B.1 provides an overview of such mechanisms: this was used in the OECD questionnaire conducted to support this work (see Annex C).

Table B.1. Agri-environmental policy mechanism classifications

<table>
<thead>
<tr>
<th>Category</th>
<th>Instrument</th>
<th>Examples</th>
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<td>Regulatory instruments</td>
<td>Environmental standards</td>
<td>Chemical bans</td>
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<td>Agricultural input standards</td>
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<td>Performance (output) standards (e.g. agricultural waste management standards)</td>
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<td>Technology standards</td>
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<td>Activity prohibitions</td>
<td>Permanent outright bans</td>
<td>Bans on undertaking an environmentally damaging activity in an agricultural area</td>
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<tr>
<td></td>
<td>Temporary outright bans</td>
<td>Bans on undertaking an environmentally damaging activity in an agricultural area</td>
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<td>Environmental property rights</td>
<td>Regulations to assign minimum</td>
<td>Environmental flow</td>
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<td>Environmental taxes</td>
<td>Performance or emissions taxes</td>
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<td></td>
<td>Input taxes (e.g. fertiliser taxes)</td>
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<tr>
<td>Economic instruments</td>
<td>Environmental subsidies</td>
<td>Cost share programmes</td>
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<td>(Agri-environmental payment</td>
<td>Payments for ecosystem services</td>
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<td>payment schemes)</td>
<td>Subsidies for agri-environmental</td>
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<td>structural adjustment towards “greener” agricultural systems</td>
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<td>Voluntary training programmes</td>
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<td>Tradeable allowances</td>
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<td>and pollution reduction credit</td>
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<td>trading</td>
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<td></td>
<td>Tradeable offset schemes</td>
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<tr>
<td>Hybrid instruments</td>
<td>Environmental “cross-compliance”</td>
<td>Cross-compliance mechanisms; baseline eligibility requirements</td>
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<td>“cross-compliance” requirements</td>
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</tbody>
</table>

Source: Adapted from OECD (2010[66]) and Hardelin and Lankoski (2018[67]).

References


OECD (2008), Agricultural policy design and implementation: a synthesis, OECD Publishing, [66]
Annex C. OECD Questionnaire on use of digital technologies by agri-environmental policy administrators

In order to gather information about OECD member governments’ current experiences with digital technologies, the Secretariat constructed a questionnaire. The questionnaire provided information on the current and expected use (within the next three years) of digital technologies to support the implementation, monitoring and evaluation of agri-environmental policies in OECD member countries. In particular, it focuses on better understanding:

- which types of data are currently used and how they are gathered
- the extent to which agri-environmental policymakers and programme managers make use of particular digital technologies in carrying out their functions as they relate to the agricultural sector, including for policy design, policy implementation, monitoring and compliance, policy evaluation, and communication
- the extent to which use of digital technologies differs across agri-environmental policy areas
- strategies or management policies organisations are putting in place maximise their beneficial use of digital technologies
- organisations’ experiences with digital technologies and future plans.

Four members volunteered to participate in the testing of the questionnaire: Canada, Chile, New Zealand and the Netherlands. The test questionnaire was sent to participants on 18 January 2018, for return on 23 February 2018.

The Questionnaire received 46 responses covering 67 institutions (some responses consolidated data from several institutions) from 16 OECD member countries, plus the European Commission’ Directorate-General for Agriculture (see Table C.1.). These responses provided data on 108 policies and programmes, as well as respondents’ experiences with and views on use of digital technologies by their organisation. This dataset provides a wealth of information on how digital technologies are currently being used by reporting organisations.
Table C.1. OECD Questionnaire Respondent List

<table>
<thead>
<tr>
<th>Country</th>
<th>Institution</th>
<th>Acronym</th>
<th>Individual national organisation</th>
<th>Individual sub-national organisation</th>
<th>Consolidated response collated by lead agency</th>
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*Note: Cons. = Consolidated response.*

*Source: OECD Questionnaire.*