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Digital Innovations in the Bioeconomy

Welcome to the February issue of the Technology Innovation Management Review. We invite your comments on the articles in this issue as well as suggestions for future article topics and issue themes.

Carleton University

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Overview
The Technology Innovation Management Review (TIM Review) provides insights about the issues and emerging trends relevant to launching and growing technology businesses. The TIM Review focuses on the theories, strategies, and tools that help small and large technology companies succeed.

Our readers are looking for practical ideas they can apply within their own organizations. The TIM Review brings together diverse viewpoints —from academics, entrepreneurs, companies of all sizes, the public sector, the community sector, and others —to bridge the gap between theory and practice. In particular, we focus on the topics of technology and global entrepreneurship in small and large companies.

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Editorial: Digital Innovations in the Bioeconomy

Iivari Kunttu, Guest Editor

Welcome to the February issue of the *Technology Innovation Management Review*. As guest editor, it is my pleasure to introduce this month's editorial theme covering a variety of topics on actual theme of digital innovations in bioeconomy.

Climate change caused by increased carbon emissions into the Earth's atmosphere is leading to huge challenges for several areas of everyday life. Building a climate-smart bioeconomy in response to this is a key goal that considerable amounts of efforts, both among research community and practitioners, have been dedicated towards in recent years (Campbell et al., 2014; Rose & Chilvers, 2018). Developing sustainable solutions and research-based innovations to minimize the environmental impacts of food production has been a focal area in the field, particularly about minimizing carbon emissions in the production process. Along with new technologies, systematic monitoring, analysis, and simulation of climate change impact, comes the need for a deeper understanding of sustainable processes to utilize natural resources. This plays a central role in finding answers to the huge environmental challenges (Arulnathan, 2020).

The topic of digitalization in the bioeconomy and agriculture was selected as one of the main themes in the first *Open Bioeconomy Conference* held in Hämeenlinna, Finland, in September 2020. This conference was meant to be the beginning of an annual meeting that brings together bioeconomy researchers and practitioners (https://openbioeconomyweek.org/). Two of the papers presented in this special issue are based on presentations from that conference.

The focus of this special issue is to highlight current research, innovations, trends, and future directions of the bioeconomy through the lens of digitalization and data utilization (Kunttu, 2020). Our aim is to highlight and underline some of the significant improvements that digitalization can bring to the bioeconomy field. In this manner, the issue is built around themes involving digitalization in the development of bioeconomy research, innovations, and business, particularly in the areas of climate-smart food and biomass production. This area is often referred as "smart agriculture" (Campbell et al., 2014), to which two of the papers are directly related.

In the opening paper, **Olli Niemitalo et al.** provide a report on the utilization of drone imaging in agriculture, forestry, and the green areas of cities. The paper describes how digital imaging and image analysis provide a wide variety of opportunities to support, manage, and monitor plant production based on data collected from the field, and thus support practices of farming and forestry. The authors also publish a remarkable set of drone image data for experimental use.

In the second paper, **Ilpo Pölönen et al.** present a practical use case that utilizes an Internet-of-Things (IoT) approach to smart agriculture. The paper introduces an automatic digital tracking and monitoring system for round feed bales on farms that utilizes a wide variety of field data obtained during the baling and delivery process.

The third paper, authored by **Essi Ryymin**, studies digitalization in the bioeconomy from the viewpoint of education and lifelong learning. The paper conducts research on perceptions of bioeconomy teachers at an Applied Sciences University in Finland regarding digitalization in the rapidly developing and disruptive area of smart bioeconomy.

The final paper by **Olli Koskela et al.** shows how computational simulation can be used to plan and optimize the logistics related to producing renewable fuels from waste in local biorefinery units. The simulation tool presented was developed to allow users to explore the effectiveness and impact of a local biorefinery in waste management. The paper reports on the results of testing this tool with multiple delivery options and waste locations.

The contributions included in this special issue of the TIM Review provide insights into the rapid digitalization and data-driven development currently taking place in the area of bioeconomy and food production. My hope is that the content of this special issue will be of interest to the TIM Review audience, as well as scholars and practitioners contributing to these areas. The importance of pursuing a climate-smart bioeconomy with digitized agricultural production and delivery has become even greater as we look to move forward out of a global pandemic with more sustainable use of natural resources.

Iivari Kunttu
Guest Editor

Editorial: Digital Innovations in the Bioeconomy

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References

Arulnathan, V. 2020. Farm-level decision support tools: A review of methodological choices and their consistency with principles of sustainability assessment. *Journal of Cleaner Production*, 256.

Campbell, Bruce M., Thornton, P., Zougmoré, R., van Asten, P., Lipper, L. 2014. Sustainable intensification: What is its role in climate smart agriculture? *Current Opinion in Environmental Sustainability*, Volume 8: 39-43. https://doi.org/10.1016/j.cosust.2014.07.002

Kunttu, I. 2020. Collaboration Network Creation and Utilization in a Digital Bioeconomy Ecosystem. In: Kantola J., Nazir S., Salminen V. (eds) *Advances in Human Factors, Business Management and Leadership*. AHFE 2020. Advances in Intelligent Systems and Computing, vol 1209. Springer, Cham. https://doi.org/10.1007/978-3-030-50791-6_7

Rose, D.C., Chilvers, J. 2018. Agriculture 4.0: Broadening Responsible Innovation in an Era of Smart Farming. *Frontiers in Sustainable Food Systems*, Vol. 2. https://www.frontiersin.org/article/10.3389/fsufs.2018.00087

The TIM Review currently has a Call for Papers on the website for a special edition on "Distributed Ledger Technologies and Smart Digital Economies" (June 2021). For future issues, we invite general submissions of articles on technology entrepreneurship, innovation management, and other topics relevant to launching and scaling technology companies, and for solving practical business problems in emerging domains such as artificial intelligence and blockchain applications in business. Please contact us with potential article ideas and submissions, or proposals for future special issues.

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A Year Acquiring and Publishing Drone Aerial Images in Research on Agriculture, Forestry, and Private Urban Gardens

Olli Niemitalo, Eero Koskinen, Jari Hyväluoma, Outi Tahvonen, Esa Lientola, Henrik Lindberg, Olli Koskela & Iivari Kunttu

> *A single observation that is inconsistent with some generalization points to the falsehood of the generalization, and thereby 'points beyond itself'.*
>
> Ian Hacking
> Philosopher of science

Drone imaging has been shown to have increasing value in monitoring and analysing different kinds of processes related to agriculture and forestry. In long-term monitoring and observation tasks, huge amounts of image data are produced and stored. Environmental drone image datasets may have value beyond the studies that produced the data. A collection of image datasets from multiple data producers can, for example, provide more diverse training input for a machine learning model for vegetation classification, compared with a single dataset limited in time and location. To ensure reproducible research, research data such as image datasets should be published in usable and undegraded form, with sufficient metadata. Timely storage in a stable research data repository is recommended, to avoid loss of data. This work presents research datasets of 2020 drone images acquired from agricultural and forestry research sites of Häme University of Applied Sciences, and from Hämeenlinna urban areas. Those images that do not contain personal data are made freely available under a Creative Commons Attribution license. For images containing personal data, such as images of private homes, privacy-preserving forms of data sharing may be possible in the future.

Introduction

The development of digitalization and measurement technologies in recent decades has enabled digital devices and sensors to produce huge amounts of data that has great potential in optimizing processes related to production chains or service production. In the field of bioeconomy, the main production processes are related to food and biomass production. Digitalization provides a wide variety of opportunities to support, manage, and monitor production based on data collected from the field.

Image-based data collection and analysis provides a huge potential to support these goals. Visual data collected from agricultural fields enables automated analysis tasks and can provide real-time information on production status. To acquire suitable visual information, basically two different alternatives exist: remote sensing based on satellite imaging, and drone (that is, unmanned aerial vehicle, UAV) imaging. In this paper, the main application fields studied are agriculture, forestry, and private urban gardens, in all of which remote sensing imaging can have many different purposes.

Precision farming technologies aim to optimize the use of farming inputs both spatially and temporally for improved economic outcomes and reduced environmental impacts of farming. In precision farming, a field is considered as a heterogeneous entity with variable topography, soil properties, weed infestation, and yield potential, whereby management practices are tailored spatially and temporally (Finger et al., 2019). Precision farming thus strongly relies on site-specific sensing of variables that are essential for management decisions. Georeferencing techniques and spatial mapping are important elements in precision farming.

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Spatial information can be collected with scanners mounted in tractors (Pallatino et al., 2019) or using satellite imagery (Segarra et al., 2020).

As well, drones have increasingly been used to collect data on several features relevant for precision agriculture (Tsouros et al., 2019). Compared with satellite-based remote sensing, drone technology can produce images with considerably higher spatial resolution in the centimeter range. Also, the temporal resolution of drone-based imagery can be decided by the user, which leads to flexibility in comparison with satellite data. Drones have also been used for research purposes in monitoring field experiments (Viljanen et al., 2018, Dehkordi et al., 2020). Non-destructive monitoring of vegetation is a major benefit for practical agronomy as well as for research use. Drone aerial imaging has been utilized in a wide range of agricultural applications.

Some of the most common applications of drone imaging in precision agriculture are weed mapping and management, vegetation growth monitoring and yield estimation, vegetation health monitoring, and irrigation management (Tsouros et al., 2019). Imaging has been used in monitoring many vegetation traits, for example, biomass amount (ten Harkel et al., 2020), nitrogen status (Caturegli et al., 2016), moisture and plant water stress status (Hoffmann et al., 2016), temperature (Sagan et al., 2019), and various vegetation indices (Viljanen et al., 2018). Deep learning-based prediction of crop yield from drone aerial images has also shown promising results (Nevavuori et al., 2019, Nevavuori et al., 2020).

In the field of forestry, drone-based photogrammetric methods can be used in several different ways. The methods used may provide general forest inventory data that focuses on common stand variables such as volume and height (Tuominen et al., 2017). Practical forest planning in Finland based on drone-collected photogrammetric data is rapidly advancing and is currently being piloted. Drones have proven especially useful in detection and inventory of various forest damage areas, such as windthrow areas (Mokros et al., 2017, Panagiotidis et al., 2019) and bark beetle outbreak areas (Näsi et al., 2015, Briechle et al., 2020). Drones have been successfully used in various forest fire suppression and prevention tasks for several years (Ollero et al., 2006, Akhloufi et al., 2020). Increasing demand to safeguard forest biodiversity has also encouraged the use of photogrammetry-based methods. These methods have proven to be a useful inventory tool, when important structural factors such as keystone species like aspen (Viinikka et al., 2020), standing dead trees (Briechle et al., 2020), or coarse woody debris (Thiel et al., 2020) are located in a forest landscape.

In the area of private urban gardening, drone-based imaging may provide new approaches to monitor the effects of gardening practices on the vegetation and on carbon sequestration. In low-density housing areas, the surface coverage pattern is typically very diverse, consisting of numerous individual plots and gardens. Homeowners reshape and modify private domestic gardens based on personal preferences and individual gardening practices. The role and meaning of vegetation and gardening practices vary, resulting in plot-to-plot variations in carbon sequestration and evapotranspiration, which affects stormwater management and the degree of reduction in the urban heat island phenomenon. Approaches to sustainable urban development have put an increasing interest in low-density housing areas that cover large areas in cities. A single plot is not the main focus, but rather the entity they form together. This raises the challenge to find suitable methods for easily studying the on-going changes at multiple scales to provide data both on the quality and quantity of vegetation. Plot and block scale choices and elements define housing area scale attributes.

This article describes vegetation monitoring-related aerial image acquisition by Häme University of Applied Sciences (HAMK) using drones, in 2020, both the processes and experiences gained. Apart from the image data, the main research in three areas is to be published separately. In total, approximately 200,000 image files, approximately 1 TB in size, are in the process of being published openly (see *Data Availability*). Particular features of the presented datasets are including the original image files, using a multispectral camera, and that one of the research sites, Mustiala biochar field, was imaged several times over the growing season with some near-simultaneous satellite imagery available from public sources. Based on a search by the authors using Google Dataset Search (https://datasetsearch.research.google.com/) at the time of writing, drone aerial image datasets are rapidly increasing in number, but are typically orders of

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magnitude smaller than the datasets presented in this work and do not usually include the original image files, although they may be available upon request. In this article, we also discuss the benefits and challenges of publishing drone image datasets.

Methods

Drone aerial image datasets were collected from multiple sites in Kanta-Häme, in southern Finland. Three of the sites (Fig. 1) are presented in this work:

1. *Mustiala biochar field* (Fig. 6) is located at the Mustiala educational and research farm of Häme University of Applied Sciences, in Tammela (60˚49' N, 23˚45'24'' E). The biochar experiment consists of 10 adjacent plots, each of size 10 m × 100 m (1000 m²), and with a total area of 1 ha. Biochar soil amendment was applied on five of the plots at a rate of ca. 20 t/ha. The other five plots were control treatments without biochar amendment. Ground control points (GCPs) were placed covering the field in a roughly 100 m × 100 m die face-5 pattern (see Fig. 6). GCPs were 29 cm × 29 cm sized black-and-yellow 2x2 checkerboard-style cut-outs of A3 prints. They were georeferenced with the aid of a real-time kinematics (RTK) capable Trimble Geo 7X (H-Star) hand-held GPS receiver.

2. *Evo old forest* (Fig. 3) consists of seven separate stands all located in the Evo state forest. The stands, with a pooled area of 160 ha, are dominated by mature Norway spruce (Picea abies) with an age range of 80-120 years. All stands have a rather high amount of dead standing trees, known to be important for biodiversity, for example, for cavity-nesting birds. The standing dead trees were catalogued in 2019-2020 to function as reference data for photogrammetric methods.

3. *Hämeenlinna private urban gardens* consist of approximately 5-10 domestic gardens in the sparsely populated urban areas of Hämeenlinna.

The drone used in all of the imaging missions was a DJI Matrice 210 RTK V2 quadcopter camera drone. The camera payload for each mission was selected (see Fig. 2) from the following cameras:

1. *DJI ZenMuse X5S FC6520* —a 3-axis gimbal-stabilized RGB camera with a 15 mm focal length lens, operated in sRGB JPEG still mode, software version 01.07.0044,

2. *DJI ZenMuse XT2* (radiometric) —a 3-axis gimbal-stabilized camera with a 13 mm focal length lens for the thermal sensor operated in radiometric JPEG mode, and an 8 mm focal length lens for the RGB sensor, software version 06.02.20, and

3. *Micasense Altum* —a radiometric multispectral camera with dedicated optics for each channel, separately timed and triggered from the other cameras, software version 1.3.6, with sunlight sensor DLS2.

Flights were planned in Dji Pilot software. Flight parameters were specified as best fit for the present environment, light and weather conditions, area size, and camera type. Flight parameters for Evo old forest

Figure 1. Research site locations (white dots) in Finland.

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were the following: altitude 120 m above ground, side overlap 80%, frontal overlap 80%, speed 3-5 m/s, camera triggering mode: time interval. For the Mustiala biochar field, the following parameters were mostly used: altitude 80 m, side overlap 85%, frontal overlap 83%, and speed 2-3 m/s. The field was imaged multiple times over the growing season, using identical parameters. For Hämeenlinna private urban gardens, flight parameters were as follows: altitude 50 m, side overlap 85%, frontal overlap 85%, and speed 3 m/s. When cameras were used simultaneously, overlap was specified for the Micasense Altum, resulting in a higher overlap for other cameras. Flights were scheduled (Fig. 2) between 11.00 am and 15.00 pm (UTC+3), from May to August 2020.

The DJI gimbal cameras were nadir-pointing, that is, straight down, and synchronously triggered by the DJI Pilot software. The Micasense Altum was triggered by its own timer and pointed straight down in the drone's internal coordinate system. The Micasense Altum images of a Micasense calibrated reflectance panel (Fig. 5) were taken before or after each imaging mission, or both. A Geotrim Trimnet VRS virtual RTK station was used, while the DJI cameras received RTK GPS information from the drone. The Micasense Altum utilized its own GPS receiver.

For the figures used in this article, Agisoft Metashape Professional version 1.7.0 (Agisoft 2020a) was used to color-correct the Micasense Altum images and to generate an orthomosaic of the Mustiala biochar field using the workflow described in Agisoft (2020b), without the use of ground control points. For Figures 5 and 7, single Micasense Altum photos from the Mustiala biocarbon field mission dated 2020-05-22, 10:00–12:00 (UTC), were exported in calibrated form from Agisoft MetaShape, and their blue, green, and red spectral channels were stacked (aligned) in Adobe PhotoShop version 21.2.4 with distortion correction. The Micasense Altum radiance and reflectance images (Figs. 4-7) and the Sentinel-2 satellite image of Figure 6 were converted to the sRGB color space in GIMP version 2.10.18 by assigning an sRGB gamma=1 color profile, by adjusting brightness in the curves tool using a linear ramp crossing the origin, and by converting to sRGB color profile using a relative colorimetric rendering intent. Geographical illustrations were made in QGIS version 3.12.2 (QGIS Development Team 2020).

For a comparison with the aerial images, a Sentinel-2 satellite image (Fig. 6) of the Mustiala biochar field was manually selected and retrieved from the Copernicus Open Access Hub (Copernicus Sentinel Data 2020) for a cloud-free day that coincided with a drone imaging mission on 2020-05-22. For Figure 7, machine learning image segmentation of sRGB-color space images in 0.1 m / pixel resolution was done using the DroneDeploy Aerial Segmentation Benchmark U-Net model "keras baseline" run gg1z3jjr by Stacey Svetlichnaya (DroneDeploy 2019), using a tile size of 300 × 300 pixels.

Results

The GCP location data and most of the acquired aerial images are being made publicly available (see section *Data Availability*). Figure 3 shows the camera locations for all individual images taken during the Evo old forest imaging missions. Figure 4 shows a sample image from each camera from a Mustiala biochar field imaging mission on 2020-05-22. Before that flight, an image was taken of the calibrated reflectance panel (Fig. 5). Near-

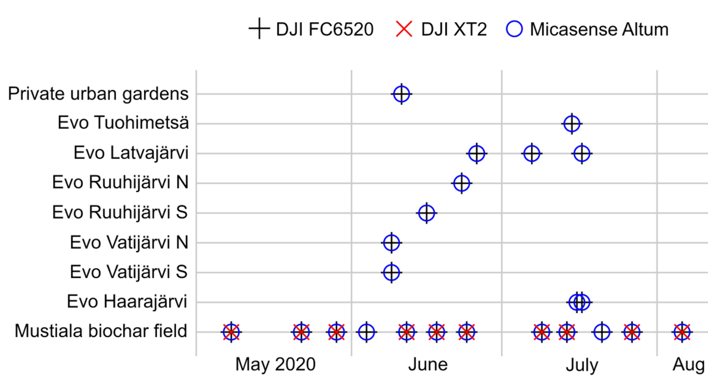

Figure 2. The 2020 imaging mission schedule for the research sites, with the camera payload indicated.

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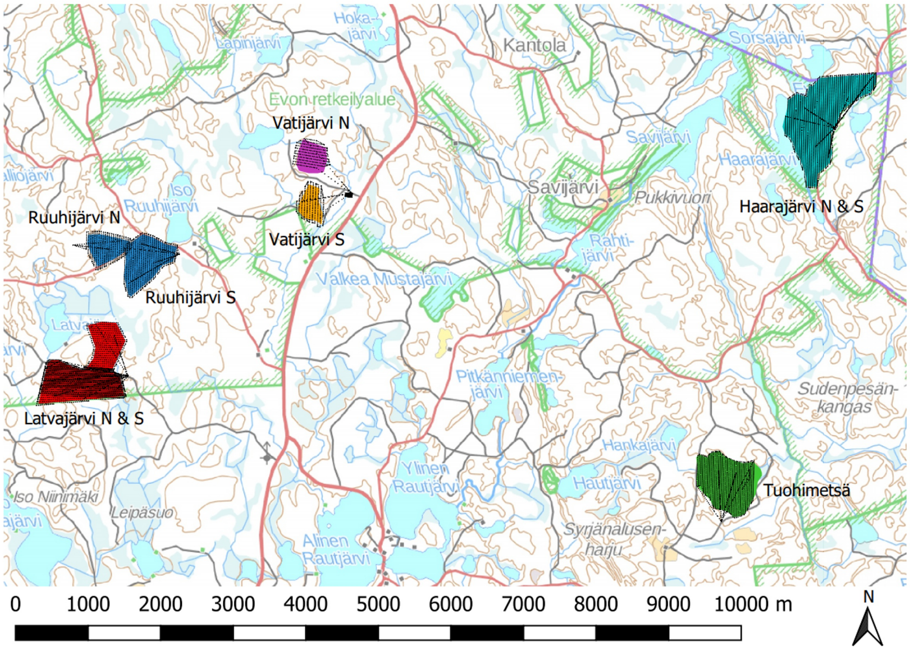

Figure 3. Evo old forest research sites (colored areas) and camera GPS locations of individual drone images (black dots). Some Micasense Altum images were taken on the way to or from the takeoff and landing site due to lack of drone-camera communication. (Map: National Land Survey of Finland Topographic Database 01/2021.)

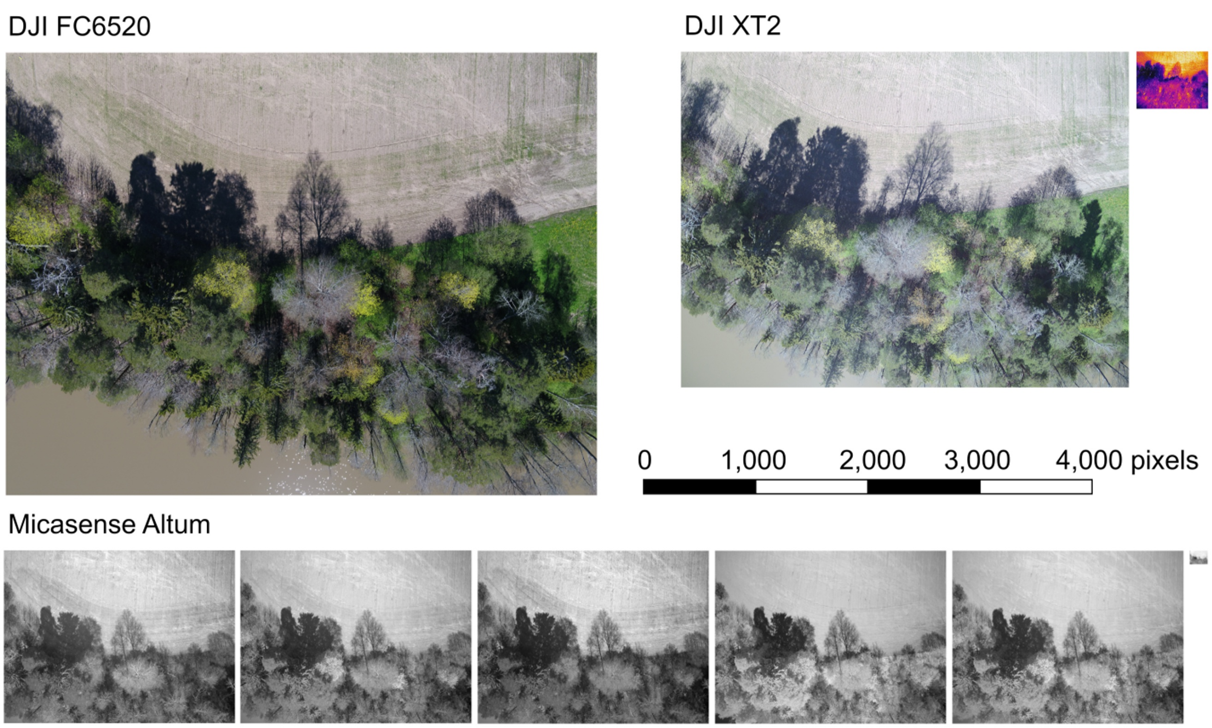

Figure 4. Uncalibrated sample drone images from Mustiala biochar field, captured with the drone flying at an altitude of 80 m from the ground. The Micasense Altum spectral channel images are (from left to right): blue, green, red, near infrared, red edge, and thermal. The DJI XT2 images were obtained on a separate flight and are visible (left) and thermal (right).

Figure 5. A calibrated reflectance panel (Micasense) placed on the Mustiala biochar field, imaged hand-held using the Micasense Altum multispectral camera.

Figure 6. The Mustiala biochar field on 2020-05-22. Left: A 4 cm resolution drone orthomosaic, an artificial view straight down, made of Micasense Altum multispectral camera images without the use of ground control points (GCPs), acquisition time 10:20 to 10:27 (UTC). The geolocation error of GCPs was at most 0.8 m. Right: A 10 m resolution Sentinel-2 satellite bottom-of-atmosphere corrected reflectance image (Copernicus Sentinel Data 2020), acquisition time 09:50 (UTC).

simultaneous drone and satellite imagery from that day are shown for comparison in Figure 6. A single image and an orthomosaic built from multiple images are presented for comparison in Figure 7, together with their machine learning image segmentation. For the Mustiala biochar field, the location of the GCPs were resolved with a horizontal and a vertical accuracy of 0.1 m, as reported in the shapefile from the hand-held RTK GPS receiver.

Discussion and Conclusions

We encountered many technical challenges during data collection. Interoperability problems between drone and camera systems from different manufacturers prevented camera triggering by the drone and tagging images with high-accuracy RTK GPS information. A possible time zone misconfiguration affected image time stamping. Although automatic flight logs were generated, they were

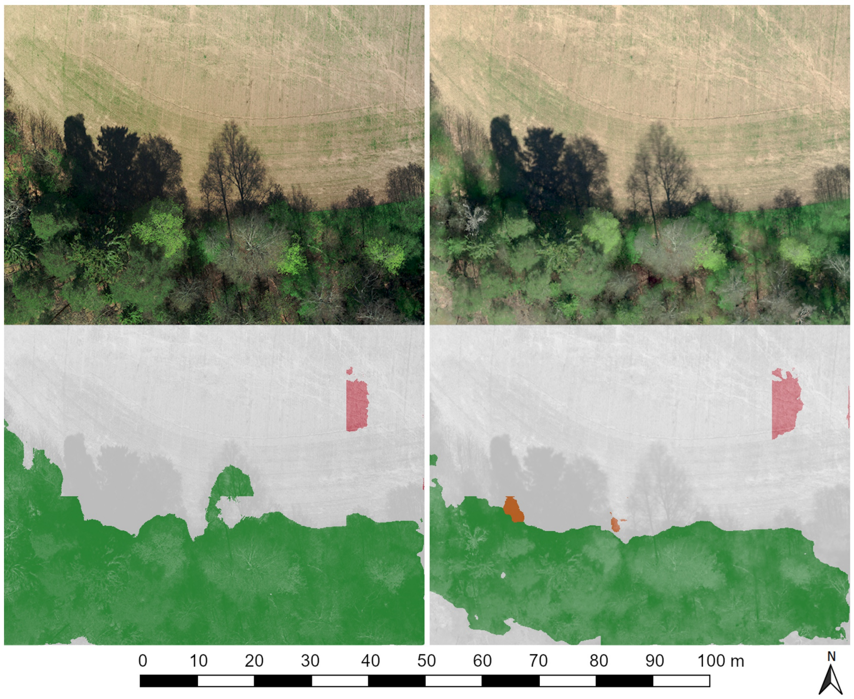

Figure 7. A single drone image (top left) aligned to a drone orthomosaic (top right), both using the Micasense Altum camera. The single image shows fine detail of complex objects better than the orthomosaic, at the cost of not being an orthoimage. Using an off-the-shelf U-Net machine learning model trained on orthomosaics (DroneDeploy 2019), the images were segmented into classes: ground (white), vegetation (green), building (red), water (orange), and cars and clutter (not found), overlaid on the single image (bottom left) and the orthomosaic (bottom right).

insufficient to answer all questions arising in later interpretation of the collected data, which resulted in increased work wrangling the data. It would be advisable for further work going forward to complement automatic logs with notes about the settings used and both operator intent and actions.

Selecting the flight parameters turned into something of an “art in itself”. Flight speed, altitude, side and frontal overlap, camera orientation, and triggering mode significantly influenced the image results. For example, flight altitude requires a compromise between image resolution and flight time. Lowering the altitude increases the flight time, which is accompanied by possible in-flight battery depletion, making further use of the images more complicated by more dynamic scenes.

For photometric applications, rapidly changing light conditions can be a problem even for short flights. As well, movement from the combination of windy weather and vegetation invalidates the assumption of a static scene, made for example in a post-processing pipeline that produces a static 3-d point cloud, either as an intermediate step or as the final product. The planning of drone aerial imaging has been studied and reviewed by (Tmušić et al., 2020), which covers choices such as camera angle and flight pattern.

Much consideration should be given to the process of publication of research data from high-resolution aerial imaging missions. Aspects to consider include data storage and availability, software compatibility, the rights of data producers, the rights of possible data subjects, license agreements of processing software, and others.

Open publication of research data improves the reproducibility of science, and reduces barriers to participating in science and utilizing scientific data and results, especially for under-resourced and under-represented participants. For academic data producers, the growing recognition of *data as research output* (see San Francisco Declaration on Research Assessment

2012) may bring financial incentives to more widely publish research data. Incentives by science funders may be applied retroactively. A major practical reason to publish research data is the possibility that a dataset may have tremendous utility value outside the research project, far beyond the organization that produced it. Many possible later uses of data cannot be anticipated at the time of its creation and collection.

Not all research data that is openly published remains available. As an example, Khan et al. (2021) were only able to retrieve 94 out of 121 open-access medical ophthalmology imaging datasets. Storing research data in an established repository such as Zenodo (https://zenodo.org/) gives a level of guarantee of data longevity. It also allows obtaining a Digital Object Identifier (DOI) for sharing and citing the data. Upon a recent successful storage quota application by HAMK, the image datasets presented in this article are being stored and published in Fairdata services, funded by the Ministry of Education and Culture (Finland). Publication of research data in a repository effectively forces the storage of the data together with metadata describing the data, ownership of the data, and its usage license. The additional information resolves many ambiguities when using the data. Structured metadata in repositories ensures the dataset is indexed in research databases.

A repository may also allow incremental publication of data. If publishing the data takes place this way, already during its collection instead of at the end of a research project, then use of and citation of the data outside of the data producing organization can start much earlier. Accelerated publication also ensures that the data or information of concern is not lost during the project or when personnel leave the project. Academic data producers typically have an interest in priority publication of their research. Early publication of general-use research data, such as the image datasets presented in this article, is less likely to conflict with that interest, compared to early open publication of all data vital to the main publication.

Location data from an image or other information about a person or object that can be associated with a person, either directly or using additional information, is likely to be considered as “personal data” by the EU’s General Data Protection Regulation (GDPR). Examples of such objects in aerial imagery include vehicles, land, and buildings managed by a private person, or by their family. GDPR requires that before personal data can be handled for a purpose, the data subject’s voluntary consent for that purpose must be obtained. A data subject also has the right to be forgotten, that is, to bindingly request that their personal data be erased without excessive delay. National laws may still allow legitimate scientific research that protects data privacy. Nevertheless, a data subject’s rights may bar redistribution or open publication of personal data under an irrevocable license, such as any of the popular Creative Commons licenses, possibly even when a data subject proactively authors the data as free speech.

The image dataset concerning Hämeenlinna private urban gardens was collected with informed consent by the data subjects, the homeowners. It was deemed necessary to deposit the data in a fully closed manner, at least for the time being, while the legal landscape of personal data is still developing. The EU has proposed a Data Governance Act (COM/2020/767 final) following a European Strategy for Data (COM/2020/66 final). The Data Governance Act defines roles and mechanisms for altruistic data sharing in managed data ecosystems. Among other things, the act is intended to streamline handling of requests by authorized users to access data, on the condition that the data subject has consented to handling of the data for the requested purpose.

Returning to our case study, unlike the presented aerial images captured mostly 80 m above ground, images from a closer range (Fig. 5) would allow distinguishing not only trees, but also individual small plants. Likewise, it would be possible to identify and count the plants and analyze their physical characteristics (allometry) and health.

Drone image data is being increasingly utilized in machine learning, as exemplified by research cited above in the Introduction. The purpose of a machine learning model might be, for example, to segment an input image into different class labels (Fig. 7). Class label masks of drone imagery could be converted to lower-resolution ground truth class density data for interpreting satellite imagery. In *semi-supervised learning*, unlabeled images would also be included to help the model better capture the natural joint probability distribution of the images and segmentation. Such uses make general-use unlabeled data valuable as a research output, thereby complementing the existing situation and future of labeled and unlabeled data. Machine learning also benefits from more diverse data, for example, from image datasets collected at an ecologically diverse set of locations. Big data in such cases can come from many small data.

Data producers may have reasons not to disclose their raw data. In such cases, other, somewhat futuristic forms of information sharing may be possible. In *federated learning*, data holders combine their efforts in a coordinated fashion to train a shared machine learning model, without communicating their original data. Alternatively, a *generative model* could be used to collect non-private artificial samples from the approximate distribution of the original data, while preserving the privacy of the original data points, typically measured by *differential privacy*. Depending on the amount of original data and required degree of privacy, generated samples may be of sufficient quality to be used similarly to the original data. For a privacy-preserving generative method suitable for images, see Chen et al. (2020).

The author of a dataset consisting of drone images may wish to limit data use. A photograph taken for scientific purposes by equipment under automatic control is unlikely to be considered as creative work and would not be protected by copyright as such. In the United States, a dataset can be copyrighted as a compilation if it is sufficiently original in selection, coordination, or arrangement, but the copyright of the dataset does not extend to any non-copyrightable data items (U.S. Copyright Office, 2021). Similarly, for EU-based authors, national implementations of the Database Directive (96/9/EC) enable copyright of a dataset as a creative collection. Separately from copyright, the directive enables sui generis protection of non-creative datasets based on substantial investment, with a 15-year term of protection (European Commission, 2018). In any case, if a separate contract is made between the dataset holder and its retriever, binding clauses in the contract may limit redistribution and use of the dataset by the retriever. For example, commercial use of a dataset by its retriever may be prohibited.

Legal aspects aside, when collecting and sharing data, care should be taken to ensure that the data will be delivered in a format that preserves sufficient quality, preferably in a format that is openly standardized, that is, not a proprietary, software-specific format. Compression artifacts that arise from lossy image compression methods such as JPEG might interfere with radiometric analyses. On the other hand, compared to lossy compression, lossless image compression results in significantly larger image files, increasing the cost of storage and transfer. Storage space requirements of image datasets could be eased somewhat by re-encoding lossless TIFF files, using a more efficient lossless method than what is available from the camera. However, rewriting the image files might also detrimentally affect metadata or other extra data, reducing the usability of the files. Image file metadata could be restored by transferring it from the original file using tools such as ExifTool and Exiv2. Usability of any modified original files should be tested at least in the most likely processing pipelines available. Rewriting of image files may be necessary to mask out personal information.

For geographical image data, it is important to also publish metadata describing the radiometric quality and the location accuracy. Information about things that affect illumination, such as clouds and sun, as well as calibration images and light sensor data, can be important for future users. Processing pipelines should be described, and when possible, source code and operation environment or information likewise included. For more information on quality assurance data and other important metadata, see Aasen et al. (2018) and Tmušić et al. (2020).

The image datasets presented in this work consist mainly of unaltered raw images directly from cameras. Publishing the raw data without embargo also became an effective way to distribute the data within the HAMK organization, as well as outside it. Another rationale behind the decision to publish not only post-processed data products, but also raw primary data, was that data users might wish to apply their own processing pipelines to ensure uniform processing of all their input data. An example of a data product is an orthomosaic (Fig. 6), which is straightforward to use in various applications and valuable in providing a visual overview of data. As demonstrated in Figure 7, the visual clarity of an orthomosaic might not be quite as high as that of the source material, the individual images, with differences that affect labeling by a machine learning model. In the future, novel photogrammetry pipelines will likely result in data products of higher quality than what is achievable using today's tools – if the raw data is still available.

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Data availability

The collected agricultural and forestry image datasets are in the process of being incrementally published under the Creative Commons by Attribution 4.0 International (CC-BY 4.0) open access license, and made available for download at (Häme University of Applied Sciences, 2021a https://doi.org/10.23729/895dfb4d-9a14-41cc-a624-727375275631 and 2021b https://doi.org/10.23729/d083d6ad-aa68-4826-8792-7a169e2d2dd9). The Hämeenlinna private urban gardens drone image dataset (Häme University of Applied Sciences 2121c) has restricted access due to personal data content. Other associated data such as calibration data and GCP coordinates are published with the datasets.

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References

Aasen, H., Honkavaara, E., Lucieer, A., & Zarco-Tejada P.J. 2018. Quantitative Remote Sensing at Ultra-High Resolution with UAV Spectroscopy: A Review of Sensor Technology, Measurement Procedures, and Data Correction Workflows. Remote Sensing. 10(7): 1091.
DOI: 10.3390/rs10071091

Agisoft 2020a. Agisoft MetaShape Professional (Version 1.7.0) (Software).
http://www.agisoft.com/downloads/installer/

Agisoft 2020b. MicaSense Altum processing workflow (including Reflectance Calibration) in Agisoft Metashape Professional.
https://agisoft.freshdesk.com/support/solutions/articles/31000148381-micasense-altum-processing-workflow-incl-reflectance-calibration-

Akhloufi, M., Castro, N., & Couturier, A. 2020. Unmanned Aerial Systems for Wildland and Forest Fires: Sensing, Perception, Cooperation and Assistance. arXiv:2004.13883 [cs.RO]. *Drones*, 5(1): 15.
DOI: 10.3390/drones5010015

Briechle, S., Krzystek, P., & Vosselman, G. 2020. Classification of tree species and standing dead trees by fusing UAV-based lidar data and multispectral imagery in the 3D deep neural network PointNet++. *ISPRS Annals of the Photogrammetry, Remote Sensing and Spatial Information Sciences*, 2: 203-210.
DOI: doi.org/10.5194/isprs-annals-v-2-2020-203-2020

Carlini N., Tramer F., Wallace E., Jagielski M., Herbert-Voss A., Lee K., Roberts A., Brown T., Song D., Erlingsson U., Oprea A., & Raffel C. 2020. Extracting Training Data from Large Language Models.
DOI: arXiv:2012.07805 [cs.CR].

Caturegli, L., Corniglia, M., Gaetani, M., Grossi, N., Magni, S., Migliazzi, M., Angelini, L., Mazzoncini, M., Silvestri, N., Fontanelli, M. & Raffaelli, M. 2016. Unmanned aerial vehicle to estimate nitrogen status of turfgrasses. *Plos One*, 11(6): 0158268.
DOI: 10.1371/journal.pone.0158268

Chen, D., Orekondy, T., Fritz, M. 2020. Gs-wgan: A gradient-sanitized approach for learning differentially private generators.
DOI: arXiv:2006.08265 [cs.LG].

Dehkordi, R.H., Denis, A., Fouche, J., Burgeon, V., Cornelis, J.T., Tychon, B., Gomez, E.P., Meersmans, J. 2020. Remotely-sensed assessment of the impact of century-old biochar on chicory crop growth using high-resolution UAV-based imagery. *International Journal of Applied Earth Observation and Geoinformation*, 91: 102147.
DOI: /10.1016/j.jag.2020.102147

DroneDeploy. 2019. Aerial Segment by DroneDeploy.
https://wandb.ai/dronedeploy/dronedeploy-aerial-segmentation/benchmark/.

European Commission. 2018. Commission staff working document: Evaluation of Directive 96/9/EC on the legal protection of databases.
https://ec.europa.eu/digital-single-market/en/news/staff-working-document-and-executive-summary-evaluation-directive-969ec-legal-protection.

Finger, R., Swinton, S.M., El Benni, N., Walter, A. 2019. Precision Farming at the Nexus of Agricultural Production and the Environment. *Annual Review of Resource Economics*, 11(1): 313-335.
DOI: 10.1146/annurev-resource-100518-093929

ten Harkel, J., Bartholomeus, H., Kooistra, L. 2020. Biomass and Crop Height Estimation of Different Crops Using UAV-Based Lidar. *Remote Sensing*, 12(1): 17.
DOI: /10.3390/rs12010017

Hoffmann, H., Jensen, R., Thomsen, A., Nieto, H., Rasmussen, J., & Friborg, T. 2016. Crop water stress maps for an entire growing season from visible and thermal UAV imagery. *Biogeosciences*, 13(24): 6545-6563.
DOI: /10.5194/bg-13-6545-2016

A Year Acquiring and Publishing Drone Aerial Images in Research on Agriculture, Forestry, and Private Urban Gardens *Olli Niemitalo, Eero Koskinen, Jari Hyväluoma, Outi Tahvonen, Esa Lientola, Henrik Lindberg, Olli Koskela, Iivari Kunttu*

Häme University of Applied Sciences 2021a. Drone image dataset: Evo old forest 2020. https://doi.org/10.23729/895dfb4d-9a14-41cc-a624-727375275631.

Häme University of Applied Sciences 2021b. Drone image dataset: Mustiala biochar field 2020. https://doi.org/10.23729/d083d6ad-aa68-4826-8792-7a169e2d2dd9.

Häme University of Applied Sciences 2021c. Drone image dataset: Hämeenlinna private urban gardens 2020. https://doi.org/10.23729/0b8dba76-0e7f-48ad-9979-462ed9d49021.

Khan, S.M., Liu, X., Nath, S., Korot, E., Faes, L., Wagner, S.K., Keane, P.A., Sebire, N.J., Burton M.J, Denniston, A.K. 2020. A global review of publicly available datasets for ophthalmological imaging: barriers to access, usability, and generalisability. *The Lancet Digital Health*, 3 (1): e51-e66. DOI: 10.1016/s2589-7500(20)30240-5

Micasense 2020. RedEdge Camera Radiometric Calibration Model. https://support.micasense.com/hc/en-us/articles/115000351194-RedEdge-Camera-Radiometric-Calibration-Model

Mokros, M., Výbošt'ok, J., Merganič, J., Hollaus, M., Barton, I., Koreň, M., Tomaštík, J., Čerňava, J. 2017. Early Stage Forest Windthrow Estimation Based on Unmanned Aircraft System Imagery. *Forests*, 8(9): 306. DOI: 10.3390/f8090306

Nevavuori, P., Narra, N., Lipping, T. 2019. Crop yield prediction with deep convolutional neural networks. *Computers and electronics in agriculture*, 163: 104859.

DOI: //doi.org/10.1016/j.compag.2019.104859

Nevavuori, P., Narra, N., Linna, P., & Lipping, T. 2020. Crop Yield Prediction Using Multitemporal UAV Data and Spatio-Temporal Deep Learning Models. *Remote Sensing*, 12(23): 4000. DOI: 10.3390/rs12234000

Näsi, R., Honkavaara, E., Lyytikäinen-Saarenmaa, P., Blomqvist, M., Litkey, P., Hakala, T., Viljanen, N., Kantola, T., Tanhuanpää, T.-M., Holopainen, M. 2015. Using UAV-based photogrammetry and hyperspectral imaging for mapping bark beetle damage at tree-level. *Remote sensing*, 7(11): 15467-15493. DOI: 10.3390/rs71115467

Ollero, A. and Merino, L., 2006. Unmanned aerial vehicles as tools for forest-fire fighting. *Forest Ecology and Management*, 234(1): S263. DOI: 10.1016/j.foreco.2006.08.292

Panagiotidis, D., Abdollahnejad, A., Surový, P. and Ku elka, K., 2019. Detection of fallen logs from high-resolution UAV Images. *New Zealand Journal of Forestry Science*, 49. DOI: 10.33494/nzjfs492019x26x

QGIS Development Team (2020). QGIS Geographic Information System. *Open Source Geospatial Foundation Project*. http://qgis.osgeo.org

Sagan, V., Maimaitijiang, M., Sidike, P., Eblimit, K., Peterson, K.T., Hartling, S., Esposito, F., Khanal, K., Newcomb, M., Pauli, D., Ward, R., 2019. UAV-based high resolution thermal imaging for vegetation monitoring, and plant phenotyping using ICI 8640 P, FLIR Vue Pro R 640, and thermomap cameras. *Remote Sensing*, 11(3): 330. DOI: 10.3390/rs11030330

San Francisco Declaration on Research Assessment. 2012. https://sfdora.org/read/

Segarra, J., Buchaillot, M.L., Araus, J.L., Kefauver, S.C. 2020. Remote sensing for precision agriculture: Sentinel-2 improved features and applications. *Agronomy*, 10(5): 641. DOI: 10.3390/agronomy10050641

Thiel, C., Mueller, M.M., Epple, L., Thau, C., Hese, S., Voltersen, M., & Henkel, A., 2020. UAS Imagery-Based Mapping of Coarse Wood Debris in a Natural Deciduous Forest in Central Germany (Hainich National Park). *Remote Sensing*, 12(20): 3293. DOI: 10.3390/rs12203293

Tmušić, G., Manfreda, S., Aasen H., James, M.R., Gonçalves, G., Ben-Dor, E., Brook, A., Polinova, M., Arranz, J.J., Mészáros, J., Zhuang, R., Johansen, K., Malbeteau, Y., de Lima, M.I.P., Davids, C., Herban, S., and McCabe, M.F. 2020. Current Practices in UAS-based Environmental Monitoring. *Remote Sens*ing, 12(6): 1001. DOI: https://doi.org/10.3390/rs12061001

Tsouros, D.C., Bibi, S., Sarigiannidis, P.G. 2019. A review on UAV-based applications for precision agriculture. *Information*, 10(11): 349.

Tuominen, S., Balazs, A., Honkavaara, E., Pölönen, I., Saari, H., Hakala, T. and Viljanen, N., 2017. Hyperspectral UAV-imagery and photogrammetric canopy height model in estimating forest stand variables. *Silva Fennica*, 51(5). Doi: 10.14214/sf.7721

U.S. Copyright Office. 2020. Compendium of U.S. Copyright Office Practices § 101 (3d ed.), Chapter 500 & Chapter 600. https://copyright.gov/comp3/

Viinikka, A., Hurskainen, P., Keski-Saari, S., Kivinen, S., Tanhuanpää, T., Mäyrä, J., Poikolainen, L., Vihervaara, P., Kumpula, T. 2020. Detecting European Aspen (Populus tremula L.) in Boreal Forests Using Airborne Hyperspectral and Airborne Laser Scanning Data. *Remote Sensing*, 12(16): 2610. DOI: 10.3390/rs12162610

A Year Acquiring and Publishing Drone Aerial Images in Research on Agriculture, Forestry, and Private Urban Gardens *Olli Niemitalo, Eero Koskinen, Jari Hyväluoma, Outi Tahvonen, Esa Lientola, Henrik Lindberg, Olli Koskela, Iivari Kunttu*

Viljanen, N., Honkavaara, E., Näsi, R., Hakala, T., Niemeläinen, O., & Kaivosoja, J. 2018. A Novel Machine Learning Method for Estimating Biomass of Grass Swards Using a Photogrammetric Canopy Height Model, Images and Vegetation Indices Captured by a Drone. *Agriculture*, 8(5): 70. DOI: 10.3390/agriculture8050070

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http://doi.org/10.22215/timreview/1418

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Cloud-Based Approach for Tracking and Monitoring of Hay Bales in Smart Agriculture

Ilpo Pölönen, Antti Suokannas, & Antti Juntunen

" By creating a digital inventory of feed bales, cloud baling eases bureaucracy and enables fluent and reliable roughage e-commerce. "

Maaseudun Tulevaisuus
In a Finnish agricultural morning paper
Sept 27, 2019

The introduction of new technology to agriculture has resulted in enormous amounts of data and their handling and utilization challenge. Data is typically gathered from several sources such as field sensors, machines, industrial processes, different laboratories and officials. This has led to several complicated systems that are not always compatible. Farmers are confused, unaware, and face challenges in seeing the benefits for their business in relation to the time required. This paper introduces an automatic digital tracking and monitoring system for round feed bales on farms. In this system, bale data from sensors, switches, and a GPS-device in the baling machine are collected by hardware and sent to the cloud with the bale ID read from a RFID tag attached to each bale. A digital inventory of bales forms instantly, and baling can be followed on the map application with a mobile device. Data in the cloud is utilized for the farmer's user interface. The farmer can manage and do various operations with bales. An important outcome is the yield report, showing basic statistics, quantities, and qualities of bales in a digitalized field parcel. If the farmer wants to sell bales, this can easily be done with the tool. It makes sales by connecting the farmer to an e-commerce portal. A key question and challenge to be resolved involves who owns the data. All the benefits of digitalization can be achieved only with good cooperation and mutual agreement from farmers who want to have control of their data under all circumstances.

Introduction

In Finland, farm size compared with many other European countries is small, though increasing steadily. Bigger farm size in most cases enables better utilization of new technology, automation, and digitalization. With increasing farm size, a farmer's work turns more into a manager's, instead of doing the work by themselves.

A farmer's work focuses on allocating limited resources to their most important duties, while using contractors for capital intensive works. This is typically the way new technology enters agriculture in Finland also, as contractors have bigger and technologically advanced machinery. In the middle of the 2010's, use of contractors was still low compared to many other European countries. According to research from the Work Efficiency Institute (TTS), contractor use is increasing steadily (Palva, 2019).

Regarding data management, several current large projects aim to harmonize and standardize data handling and storage. A major question surrounds the ownership and management of farm data (Villa-Henriksen et al., 2020), the cornerstone for farmers' participation and cooperation to develop these systems. A project to harmonize data flow between different tractor makes and implements was launched already in the 1990's. It is called the ISO 11783 series of standards (marked name ISOBUS) "Tractors and machinery for agriculture and forestry - Serial control and communication data network". The purpose of ISO 11783 standard is to specify the method and format of data transfer between sensors, actuators, control elements, information storage, and display units, whether mounted or part of the tractor, along with any implements (Backman, 2013). The ISOBUS standard has achieved many of its objectives, but the system is continuously in developmental stages. New tractor

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models are now largely called "ISOBUS compatible", meaning that the ISOBUS implements can communicate with the tractor. However, implementations without ISOBUS properties continue flowing into the market.

A Smart Farming Technology Approach to Hay Baling

In the history of hay baling, moving from hand-held hay bales to the use of a big mechanical baler was an important milestone, not only in hay harvesting, but also in forage conservation (Wilkinsson & Rinne, 2017). For the first time, grass silage, often the main feed ingredient of dairy cows, could be packed in transportable, homogenous, tradeable, and easily transportable units.

In Finland, the first bale unit packaging trials were done in the 1980s using plastic bags, but soon plastic film replaced the bags. A modern harvesting machine chain comprises mowing, windrowing, baling and, wrapping. Machine chain to harvest grass has shrunk from 3 machines to 1. Along with the technology change and digitalization, the balers, like other agricultural machines, have changed from robust machines into digitally driven implements that contain computer, numerous sensors, and switches (Figure 1). Practically everything that happens in the baler can be seen on the cabin monitor. Therefore, two developmental steps needed to happen before cloud baling could come into reality: wrapping silage in bales, and digital control and monitoring of baling process.

Smart farming, by definition, signifies decision making based on big data collected and made sense of by smart machines (Wolfert et al., 2017). We developed the system

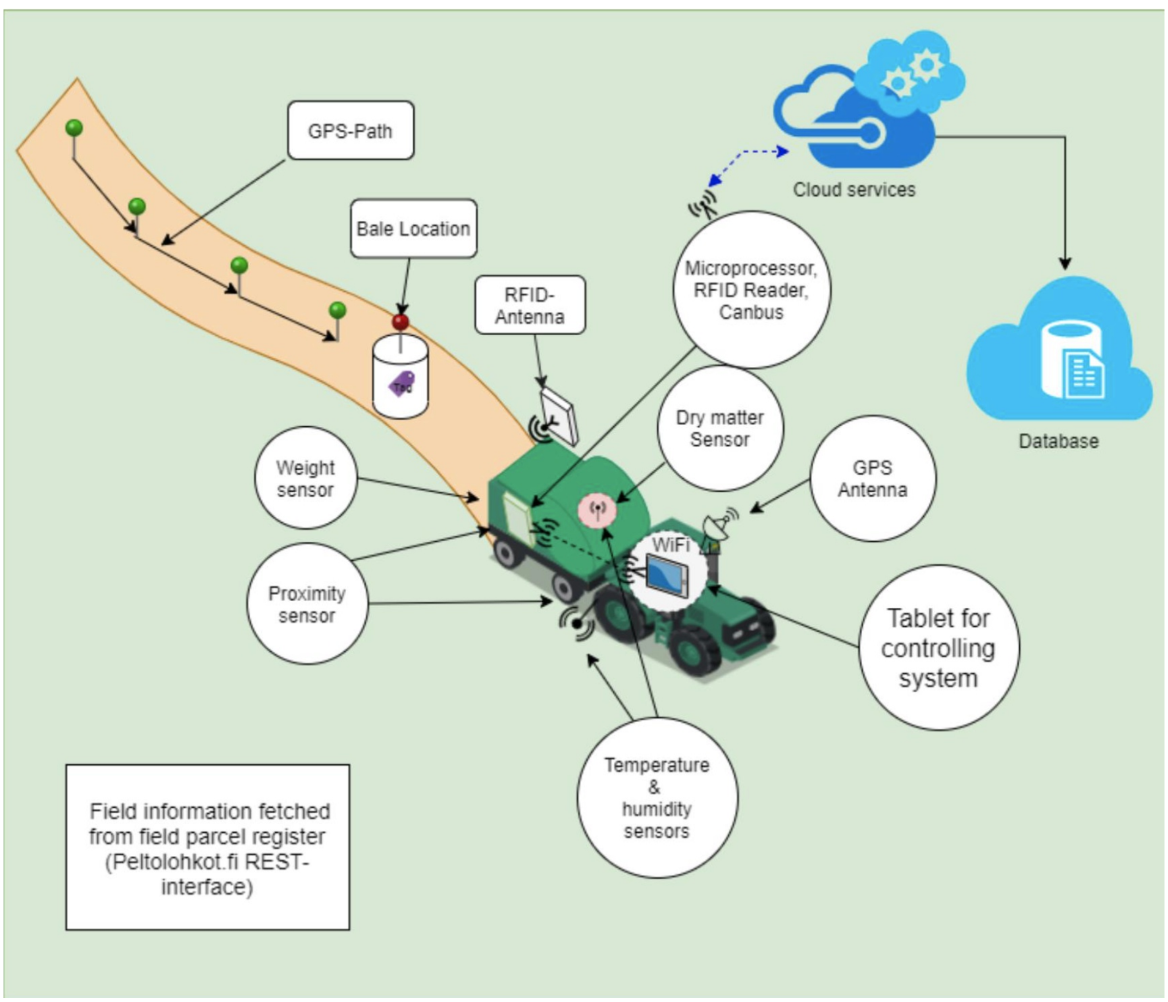

Figure 1. Overview of technical operations in cloud baling.

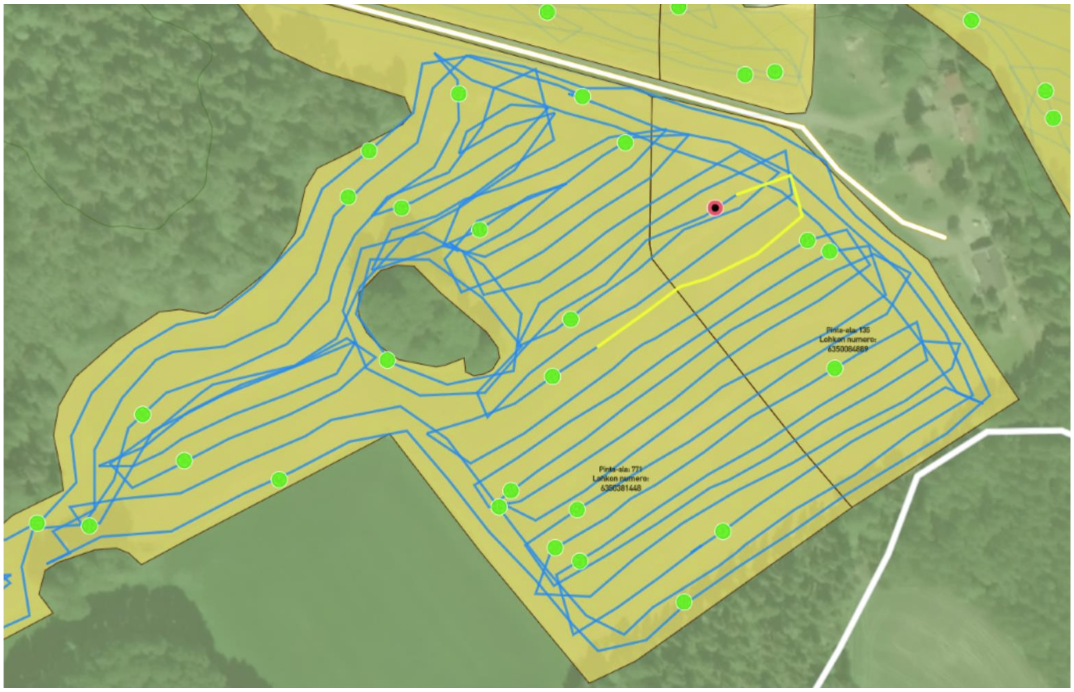

Figure 2. Cloud baling, via farmer's interface application, also produces a map with bale locations and the path baling tractor advanced. Baling can also be followed online. Even though everything is automatic, the user can observe baling on the screen and can intervene by marking problem bales which then appear red on the map.

of cloud baling to lean strongly on IoT because the data is not primarily stored locally, for example, in a baler's memory, but is rather sent to a cloud server online. By measuring yield quantity and quality (weight, dry matter, etc.), and combining it with field parcel data, cloud baling also brings hay baling into the category of precision farming. Not only parcel yield can be calculated, but also each bale's real yield can be estimated using length of a collection path (GPS) and windrow width. Cloud baling, which involves collecting large amounts of hay data into the digital cloud, is not itself an end. Rather, the primary goal is to produce information for a farmer's decision-making process, and their knowledge management (Sørensen et al., 2010).

In our application, there are two levels of information. First, by following baling as it happens online, progress in baling work can be seen (Figure 2). The immediate yield value is also given in a yield report that is available after completing the field parcel's baling (Figure 3). The farmer gets a good overview of what is going on and about the parcel's yield. Second, information from all bales in the yield can be copied from the cloud inventory into a farm management information system (FMIS). In the FMIS, bales become a part of bigger data about the parcel, as well as the whole farm. This information can then be used in planning optimal use of bales during winter feeding and for more accurate crop planning the following season.

A Proposed Solution for Cloud Baling

In our three-year project, we were able to build a proof of concept (POC) and even pilot the whole information chain of baling. The aim was to utilize RFID tagged bales that enable tracking afterwards. The technology now works, which was documented in Tran and Penttilä (2019). In the system we developed, the data from CAN-bus, various sensors, switches, and GPS-devices is collected and sent to the server (Penttilä et al., 2019). The biggest benefits of cloud baling come from the online automatic bale inventory. To fully utilize RFID tagged bales would require reading devices positioned along the harvesting-feeding chain with the required software, which we did not develop in this project. Tagged bales are nevertheless already important in bale trade, for example, in horse stables, where the certified origin of

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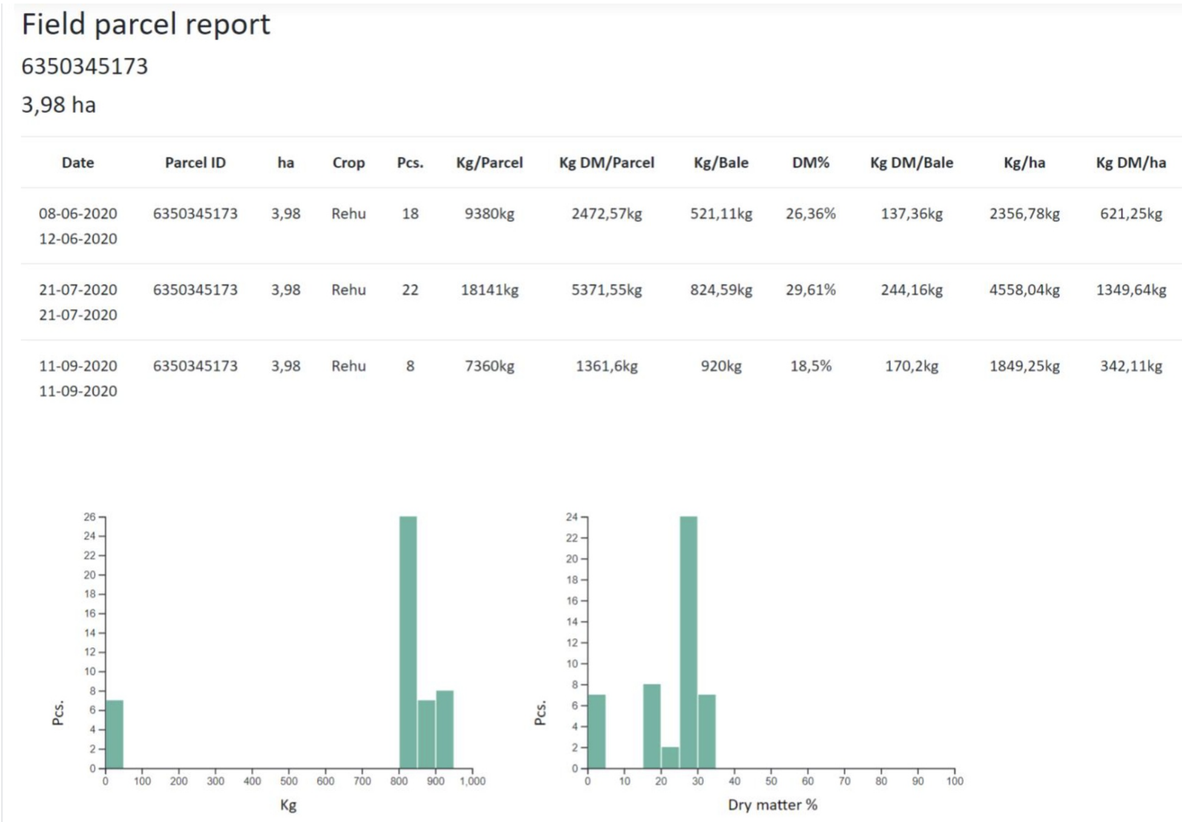

Field parcel report

6350345173

3,98 ha

Date	Parcel ID	ha	Crop	Pcs.	Kg/Parcel	Kg DM/Parcel	Kg/Bale	DM%	Kg DM/Bale	Kg/ha	Kg DM/ha
08-06-2020 12-06-2020	6350345173	3,98	Rehu	18	9380kg	2472,57kg	521,11kg	26,36%	137,36kg	2356,78kg	621,25kg
21-07-2020 21-07-2020	6350345173	3,98	Rehu	22	18141kg	5371,55kg	824,59kg	29,61%	244,16kg	4558,04kg	1349,64kg
11-09-2020 11-09-2020	6350345173	3,98	Rehu	8	7360kg	1361,6kg	920kg	18,5%	170,2kg	1849,25kg	342,11kg

Figure 3. Cloud baling's yield report shows farmer the key parameters of the harvest ie number of bales, average and total amount of fresh and dry mass on the parcel and per hectare for comparison. Variation of bale size and dry matter can be observed by glance from the graphs.

bales is appreciated. Also, where farms are regularly supervised, especially in organic farming, tagged bales would certainly be a benefit.

To our knowledge, tagging hay bales with RFID has been done earlier only with big square bales, which was commercialized by the Agco company (Agco, 2015). The system requires separate tagger machine that mounts tags on the binding twine used for the bales. Our system for round bales in contrast uses factory-made binding that is net equipped with passive RFID tags (not yet commercialized). Field tests and our three-year use of RFID tags confirm that the tags are weatherproof and can be read with near 100% certainty (Penttilä et al., 2019). An RFID serial number is read during the bale wrapping process, which is merged to the sensor data. A cloud inventory of bales is thereby formed with the real time data for each bale available from all the sensors and the GPS. Additional data such as weather information can be added afterwards.

The process of "cloud baling", as we have defined it, is not a new way of doing things in agriculture, but instead a new way of utilizing existing technology. By creating big data in the informational ecosystem it enables data mining by artificial intelligence (AI), which enhances the development of decision-making. Big data makes for better optimizing of inputs, such as fertilizers and roughage feeding, compared to earlier models.

Bale Inventory: a digitalized field parcel database

The Finnish Food Authority manages a digitalized field parcel database with an official registry of field parcels. The registry contains official information, of which parcel area is the most important, that is utilized in the administration of agricultural subsidies. In the registry, a farmer has access to only those parcels that are either in the farm's possession or under rental agreement during the growing season. Logging in to the registry requires personal authentication. A fluid process to achieve basic information on field parcels for the cloud baling interface has yet to be determined. This is not currently being done, but is on schedule to be done together with the Finnish Food Authority, in accordance with data protection legislation.

Thus, instead of requiring only a database for each farm, in our system a common national, or even international bale inventory would be formed. The idea is that all bales from each different baler would be stored in the same database. Access to the bales would be limited in the system to the bale owner, with strong authentication. Therefore, not even general calculations, statistics, or research on the bales could be done without farmer permission. In such a widespread scenario, it would be very important to achieve mutual agreement and win-win situations in data management. What we are facing is a global challenge in data ownership that hinders digitalization in general. Not only the farms themselves would benefit from a more open, communal system, but also many of the stakeholders at large.

All activities in the project were carried out principally together with farmers. Our e-commerce application was not developed starting from scratch, but rather utilized existing e-commerce experience. For the increasing needs of roughage trade, due to more fluctuating weather, and hence, varying crop yields, an e-commerce for roughage was developed two years ago by MTK, The Central Union of Agricultural Producers and Forest Owners of Finland. As a result of an API development project with MTK, an application to make sales lot of bales for the e-commerce was produced and is now available for use.

Research Questions for this Project and the Future

After the initial idea of individualizing hay bales by using a serial number and storing the data in the cloud, we faced a challenge to convince farmers and stakeholders that this system would be useful and lead to versatile benefits. During the project, several research questions emerged while implementing the idea: How does RFID technology function in the baling process? What benefits can users of the system achieve? How much money are they ready to invest in the equipment and for using the service? What stakeholders should we invite to this project? Who owns the data? And how does it all connect to FMIS? Other big questions were how to organize the data storage and what kind of database architecture we should design.

One obvious significant issue was the actual technical implementation. Fortunately, we managed to find solutions to almost all practical problems and research questions. Nevertheless, some new questions and concerns emerged at the end of the project. A challenge to be resolved is who administrates the concentrated database, develops it, and sells the service to farmers and other stakeholders.

As scientists, we would prefer to build a large cloud-based data storage, which could serve users and stakeholders in the best possible way. We have laid the foundation; almost 5,000 round bales are now in the digital bale inventory in the cloud. What should be done next in this field of development?

We believe this PoC, or actually, “pilot” version, can now be developed into a commercial product. Bale manufacturers can start making “cloud balers”, that is, equipping balers with this new innovative system. At the same time, both binding net and wrapping plastics with RFID tags should become the new industry standard.

Now that modern baling can build a technology that stores bale information in the cloud, the next project should be to try to solve and develop practices for bale and ecosystem data ownership and usage. Such a project should be international and consist of at least a few baler manufacturers. The objective of such a project would be to produce data management practices that both farmers and stakeholders will accept, and that are in accordance with the most recent international data protection legislation.

Lessons Learned

What did we learn during this process? Already at the beginning of the project, we should have contacted baler makers’ R&D departments, instead of dealers or local representatives of the brand. Instead of using our own made sensors, including compatible, bulky transformers, we could have received baling data straight from balers’ CAN-bus. Even tractors’ GPS signals could have been captured from the CAN-bus. We worked with fairly new balers, but only one out of three of them had the dry matter sensors that we particularly needed. Sensors that analyze the crop were still optional and expensive in 2018. Contractors that often invest in advanced technology did not buy accessories then,

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because they were expensive and farmers did not ask for them. Furthermore, not all farmers recognized the value of the sensors for their business.

Conclusion

In this project, we developed a new concept and application in smart farming called "cloud baling" for tracking and monitoring the hay baling process. The owners of the bales, farmers, can follow their baling progress on the map screen of a mobile device. An online and de facto inventory of bales thus forms automatically in the cloud with this digital system. The bales in the inventory have quality, quantity, and location measures that establish a good base for e-commerce, and a much-needed tool for roughage trade.

Stamping bales with RFID-tags as such is not a new technique. However, the specific way the data was managed in this project using IoT and creating a local online bale inventory, has not, to our knowledge, been reported earlier. Researchers on this project showed that the RFID-tags are durable and work both on silage bales as well as in practical farm conditions. While tagging bales alone would improve digital crop handling, cloud baling with RFID-tags brings baling further into the category of precision farming. The project not only produced a proof of concept, but also a bale inventory database, along with a roadmap for baler makers to build a commercial application.

The project has received a fair amount of publicity in Finland. Several articles about it both in paper and digital media were published. Also, baling contractors and younger farmers are welcoming cloud baling, and according to a survey are ready to pay for the service. We are now at a stage where different stakeholders are waiting for a commercial application of cloud baling to be developed. This would save farmers a lot of time of with their inventories, which some farmers prioritize as its main advantage.

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References

Backman, J. 2013.Navigation System for Modular Agricultural Machines using Optimal Control Methods and Industrial Standard Network. *Doctorial Dissertation*, Aalto University Publication series, 169/2013.

Palva, R. 2019. Urakointihintakyselyn tuloksia. Prices of agricultural contracting services, a Survey. (In Finnish). https://www.tts.fi/files/2020/urakointikyselysta_2018_4.4.2019.pdf

Penttilä, K., Suokannas, A. & Pölönen, I. 2019. Performance Evaluation of Passive Radio Frequency Identification Technology in Silage Bale Application. *Journal of Agricultural Science and Technology*, A(9): 120-130.
DOI: 10.17265/2161-6256/2019.02.006

Sørensen, C.G., Fountas, S., Nash, E., Pesonen, L., Boctis, D., Pedersen, S.M., Basso, B. & Blackmore, S.B. 2010. Conceptual Model of a Future Farm Management Information System. *Computers and Electronics in Agriculture*, 72(1): 37-47.

Tran, Q.B. & Penttilä, K. 2019. Digibale —Efficient Silage Bale Lifecycle Management. *HAMK Unlimited Journal*, 12.3.2019. Retrieved [Jan 8, 2021] from: https://unlimited.hamk.fi/teknologia-ja-liikenne/digibale-silage-bale-management

Villa-Henkriksen, A., Edwards, G.T.C., Pesonen, L.A., Green O. & Sørensen, C.A.G. 2020. Internet of Things in arable farming: Implementation, applications, challenges and potential. *Biosystems Engineering*, 191: 60-84.
DOI: 10.1016/j.biosystemseng.2019.12.013

Wilkinson, J. M. & Rinne, M. 2018. Highlights of Progress in Silage Conservation and Future Perspectives. *Grass and Forage Science*, 73(1): 40-52.
DOI: 10.1111/gfs.12327

Wolfert, S., Ge, L., Verdouw, C. & Bogaardt, M-J. 2017. Big Data in Smart Farming —A review. *Agricultural Systems*, 153: 69-80.
DOI: 10.1016/j.agsy.2017.01.023

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Perspectives from Higher Education: Applied Sciences University Teachers on the Digitalization of the Bioeconomy

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> *"If we don't change, we don't grow."*
>
> Gail Sheehy

The bioeconomy is being disrupted due to global trends of digitalization and automation. Knowledge-intensive businesses and sustainable solutions in carbon-smart food production have resulted in various consequences for the professionals working in and for bioeconomy. This paper examines bioeconomy teachers' perceptions of digitalization. It draws on research data from semi-structured focus-group interviews that were conducted with bioeconomy teachers in applied sciences higher education. The theoretical frame for the analysis was Mishra and Koehler's (2006) teacher knowledge framework for technology integration called *Technological Pedagogical Content Knowledge* (TPACK). The results suggest that although applied sciences university teachers have strong *Technological Pedagogical Knowledge* (TPK), they need more systematic approach and support to develop *Technological Content Knowledge* (TCK) in a disruptive field. Teaching in a rapidly transforming discipline, like bioeconomy, requires continuous co-development of all TPACK knowledge components by teachers.

Introduction

The term "bioeconomy" covers multiple scientific fields and interrelated perspectives highlighting biotechnology, bio-resources, and bio-ecology (Bugge et al., 2016). Several national and global policy papers (European Commission, 2012; Ministry of the Environment, Finland, 2014; Klitkou et al., 2017; OECD, 2020) have reflected on how the bioeconomy can meet digitalization as a catalysing process that results in a kind of "new industrial revolution". Digitalization in the bioeconomy is connected to applications of digital technologies, digitalized data, new and changing business models. This is happening alongside of a revolution in consumer behavior, for example, with the critical emergence of a circular economy (Klitkou et al., 2017; Satpute et al., 2017; Lamberg et al., 2020), which is important because it aims at eliminating waste and the continual use of resources by employing reuse, sharing, repair, and recycling.

The role of smart and sustainable solutions is often combined with tackling the effects of climate change and population growth. However, equally important is the connection of digital disruption with human resources and the world of work: reshaped industries require new kinds of competencies and increase the level of required skills which emphasises learning, education and training (Autor et al., 2020).

For example, in agriculture, new data-driven processes including various kinds of digital applications, smart machines, and sensors, have changed farmers' decision-making, as well as knowledge and learning needs (Ingram & Maye, 2020).

According to Klerkx and colleagues (2019), digitalization in agriculture is expected to provide technical optimization of agricultural production systems, value chains, and food systems. Further, it may help address societal concerns around farming. Klerkx and

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colleagues have investigated several recent studies on the digitalization of agriculture. They offer as examples of its societal implementation the provenance and traceability of food (Dawkins, 2017), animal welfare in livestock industries (Yeates, 2017), the environmental impact of various farming practices (Balafoutis et al., 2017), enhancing knowledge exchange and learning, using ubiquitous data (Baumüller, 2017), and improving the monitoring of crises and controversies in agricultural chains and sectors (Stevens et al., 2016).

Mulder (2017) discussed how farmers need to cope with data-driven, knowledge-intensive changes in their ecosystems. They require new solutions that create a balance between people, planet, and profit-related objectives. Some farmers may also eventually feel pressed to create new business models because of the lack of future opportunities. In the midst of these infrastructural changes, learning competence becomes crucial (Mulder, 2017). Education and teaching need to stay up to date for future professionals as the various fields, disciplines and industries rapidly develop in society.

This paper aims at examining how applied sciences university teachers in Finland perceive digitalization in the field of bioeconomy and as a part of their profession, in particular at a university of applied sciences. In Finnish, the word “professor” denotes the highest non-administrative position or rank at the universities focusing on scientific research. This paper thus instead refers to “teachers” working at a University of Applied Sciences. Such universities of applied sciences offer professionally oriented higher education on bachelor's and master's level and have strong ties with working life and regional development.

The goal of this paper is to investigate applied sciences bioeconomy teachers’ perceptions of digitalization in their work. The study aims to find out answers to the following research questions: 1) What kind of meanings do teachers give to digitalization in their work? 2) How does the digitalization of the bioeconomy connect with teachers’ *Technological Pedagogical Content Knowledge* (TPACK)?

The study wishes to contribute to a discussion of holistic impacts of digitalization on higher education teachers’ profession. In this case, we look especially at bioeconomy teachers to consider the importance for them of transforming substantial knowledge to align with pedagogical methodology.

Teachers’ Competence in the Digital Age

Digitalization challenges the work of applied sciences university teachers as well as their competences in many ways. The researcher From (2017) described a new dimension in teachers’ pedagogical skills and competences as Pedagogical Digital Competence (PDC). This relates to knowledge, skills, and attitudes that are needed to plan, conduct, evaluate, and revise ICT-supported teaching, It takes into account theory, subject and context, and supports effective student learning.

Ilomäki and colleagues (2016) investigated how digital competence is described in educational research through an analysis of 76 research articles. Based on their investigation, they suggested defining digital competence as consisting of (1) technical competence, (2) the ability to use digital technologies in a meaningful way for work, study, and in everyday life, (3) the ability to evaluate digital technologies critically, and (4) motivation to participate and commit in the digital culture.

Pozos and Torelló (2010) offer a more holistic view of applied sciences university teachers’ digital competences. They suggest these teachers’ digital competences in the integration and use of ICT means building broader capacities and abilities for new knowledge construction, knowledge management, and innovation. According to their view applied sciences teachers are agents of change, research, and innovation, who are committed to generating, applying and sharing new knowledge across society in a critical and responsible way.

The Technological Pedagogical Content Knowledge (TPACK) Framework

According to Gartner’s glossary (n.d.), “digital disruption” is “an effect that changes the fundamental expectations and behaviors in a culture, market, industry or process that is caused by, or expressed through, digital capabilities, channels or assets”. Skog and colleagues (2018) proposed the following definition of “digital disruption”: “The rapidly unfolding processes through which digital innovation comes to fundamentally alter historically sustainable logics for value creation and capture by unbundling and recombining linkages among resources or generating new ones". The "disruption" therefore refers generally to the emergence of digital products, services, and businesses that "disrupt" the current market and cause a need for re-evaluation (Kenney et al., 2015; Udovita, 2020).

Digital disruption shapes teachers' work in many ways. It requires the re-creation of teaching and learning methods with digital tools, and therefore also challenges the teaching content. Mishra and Koehler (2006, as well as Koehler et al., 2013) have developed a teacher knowledge framework for technology integration called *Technological Pedagogical Content Knowledge* (TPACK) (Figure 1). The framework incorporates three core components: *Content* (C), *Pedagogy* (P), and *Technology* (T). The more the three main domains coincide, the greater the opportunities for effective teaching with digital tools (Koehler et al., 2013; Amhag et al., 2019). Equally important are the interactions between and among bodies of knowledge covered by professors in their classrooms, represented as *Pedagogical Content Knowledge* (PCK), *Technological Content Knowledge* (TCK), *Technological Pedagogical Knowledge* (TPK), and *Technological Pedagogical Content Knowledge* (TPACK).

The framework defines *Content Knowledge* (CK) as applied sciences university teachers' knowledge about a given subject matter to be learned, which is of critical importance for teachers. This knowledge includes concepts, theories, ideas, evidence, and established practices toward developing knowledge. Inquiry and

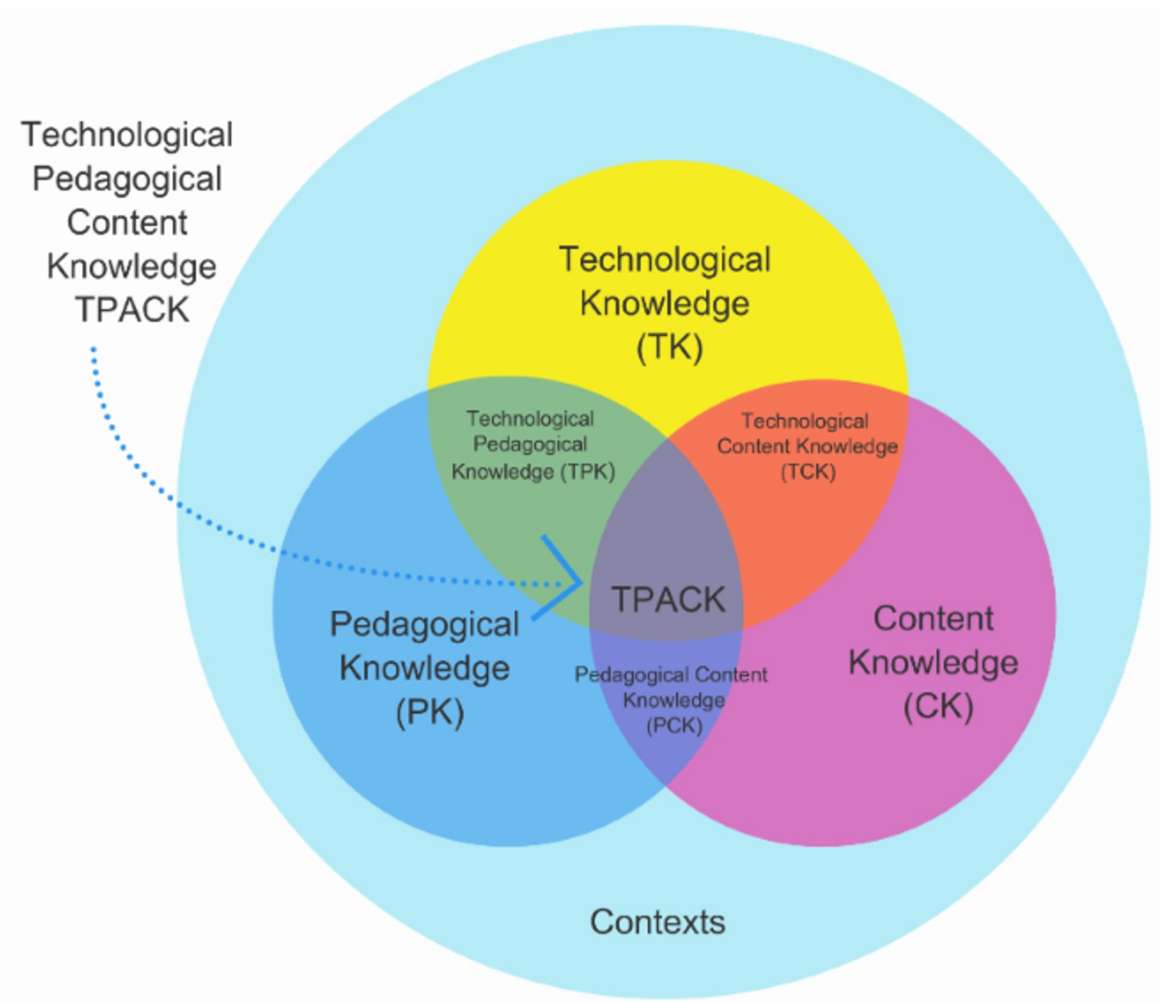

Figure 1. The TPACK framework and its knowledge components (Mishra & Koehler, 2006; Koehler et al., 2013).

knowledge differ between fields, though in each case teachers should understand their discipline's fundamentals. A second type of knowledge, *Pedagogical Knowledge* (PK) is defined as teachers' knowledge about the methods and models of teaching and learning. This form of knowledge applies to understanding how students learn, the learning process and lesson planning, assessment, and general classroom management skills. The third type, *Pedagogical Content Knowledge* (PCK) designates teachers' knowledge of pedagogy applicable to teaching specific content. PCK covers the core business of teaching, learning, curriculum, and assessment. (Mishra & Koehler, 2006; Koehler et al., 2013; Amhag et al., 2019.)

According to the framework's developers, *Technology Knowledge* (TK) is always in a state of flux; more so than the other two core knowledge domains in the TPACK framework (Koehler et al., 2013). "Technology" here can apply to all technological tools and resources, and requires mastery of information technology for information processing, communication, and problem solving. It does not posit an end state, but instead develops over a lifetime of generative, open-ended interaction with other technology. *Technological Content Knowledge* (TCK) signifies an understanding of how technology and content influence and constrain each another. Applied sciences university teachers need to understand which specific technologies are best suited for dealing with content and addressing subject-matter learning in their discipline.

Technological Pedagogical Knowledge (TPK) defines the understanding of how teaching and learning can be promoted with particular technologies in various ways. This includes knowing the pedagogical principles and constraints of a range of digital tools appropriate for pedagogical designs and strategies.

The framework treats *Technological Pedagogical Content Knowledge* (TPACK) as an emergent form of knowledge that goes beyond all three core components. It constitutes an understanding that emerges from continuous interactions among content, pedagogical, and technological knowledge. Underlying the truly meaningful and deep skill of teaching with digital tools, TPACK differs from the knowledge of each of the three concepts individually. Applied sciences university teachers should learn how pedagogical, technological, and content knowledge can interact and compensate for some of the problems students face (Koehler et al., 2013; Amhag et al., 2019). The outer circle in the framework (Figure 1) emphasizes the realization that technology, pedagogy, and content do not exist in a vacuum, but are instantiated in specific learning and teaching contexts.

Porras-Hernández and Salinas-Amescua (2013) further developed the concept of context of the TPACK-model and differentiated its levels into macro, meso, and micro contexts. The macro level context includes the social, political, technological, and economic conditions. These include the rapid technological developments worldwide, which require constant learning, as well as institutional and national policies that, in the case of technology integration by teachers, have become especially relevant. The meso context marks the social, cultural, political, organizational, and economic conditions established in the local community, as well as in the educational institution itself. The micro level context concerns in-class conditions for learning. The micro level involves resources for learning activities, norms, and policies, as well as the expectations, preferences, and goals of applied sciences university teachers and students as they interact in classrooms.

Kyllönen (2020) suggested in her recent dissertation of teachers' pedagogical use of technologies that changes in all three levels of context shape teachers' TPACK, and must therefore be given careful attention. Kereluik and colleagues (2013) commented on TPACK from the point of view of 21st century skills. They emphasized that the base of disciplinary knowledge (*Content Knowledge*, CK) encompasses both traditional content knowledge and concepts forwarded in modern frameworks, such as students having strong communication skills integrated across content areas, being metacognitive in an iterative process, engaging with complex texts, and complex problem solving. Further, they stress that knowing the technology (*Technology Knowledge*, TK) is important, but that knowing when and why to use it is more important (*Technological Pedagogical Knowledge*, TPK). Basic digital literacy skills are thus essential for both applied sciences students and teachers. Knowing when to use a particular technology for activities such as collaboration, or why to use a certain technology for acquiring specific disciplinary knowledge, constitutes an important, transferable, highly relevant type of knowledge that will not quickly become antiquated with ever-changing technological trends (Kereluik et al., 2013).

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Data Collection and Methodology

Data originate from three (3) semi-structured online focus-group interviews with bioeconomy teachers from one university of applied sciences in Finland. An open call was made, then enrollment to online focus-group sessions for interested bioeconomy teachers. The teachers were encouraged to form multidisciplinary groups with the aim of representing several disciplines. The interview offered teachers an opportunity to debate and share knowledge across the boundaries of several degree programs. Sixteen (16) interviewees in the focus-groups represented a broad range of disciplines and variety of degree programs involving the bioeconomy, for example, agriculture, bioprocess%and automation engineering, environmental engineering, forestry and horticulture. The interviewees' average working experience related to the bioeconomy was 24.3 years, and in teaching positions, 20.6 years. Every focus-group had two interviewers.

The key themes of the interviews included bioeconomy teachers' continuous learning and competence development at work, as well as their considerations related to digitalization and sustainable development in the bioeconomy. The interview themes were connected to the theoretical approaches of competence development in higher education institution teachers (Tigelaar et al., 2004; Gilis et al., 2008). Rintala and colleagues (2021) are also introducing all the interview themes from this research in more detail in an article describing bioeconomy teachers' challenges and possibilities for continuous learning at work. This paper focuses primarily on bioeconomy teachers' considerations of digitalization.

The interviews were recorded, transcribed, and analyzed.% The qualitative data analysis implemented a thematic analysis, as introduced by Braun and Clarke (Braun & Clarke, 2006; Terry et al., 2017) in the interview data analysis, which was an iterative and both theory- and data-driven process conducted by the interviewers. The theoretical framework of specific interest in the analysis was the TPACK Framework and its knowledge components.

Results

Changes in contexts support teachers' Technological Pedagogical Knowledge (TPK) development

The interviewed applied sciences university teachers connected their understanding of the meaning of digitalization to the pedagogical use of technologies. They described their methods and models in implementing digital tools in teaching, as well as student interaction, and in guiding the learning processes.

Quote 1:

> *"I think we have rather good digital competences in the degree programs of bioeconomy here. For instance, transformation to distance education (online education) was quick and flexible. We (teachers) have kind of a manner to act and think digitally. I think we bring this kind of digital know-how to our students as well. I think we are already on a good track."*

The interviewees felt that they had good *Technological Pedagogical Knowledge* (TPK): they knew how teaching and learning can be promoted with technologies, were familiar with the relevant pedagogical principles, and applied a range of digital tools for pedagogical designs and strategies. In line with Koehler and colleagues' (2013) idea of *Technological Pedagogical Knowledge* (TPK), the interviewees seemed to own a "forward-looking, creative, and open-minded mindset" in seeking to use technology for the sake of advancing student learning. Their experienced competence in TPK seemed to be linked to strong *Pedagogical Knowledge* (PK) in general. This included their understanding of how students learn, how to guide learning processes, and their general educational management skills. As the interviewees were quite experienced applied sciences teachers, they were also very familiar with their curricula, the subject matters of the discipline to be learned, and the theories, ideas and established practices of their disciplines. This mirrored good *Content Knowledge* (CK).

In line with the suggestion of Kyllönen (2020), the changes in the contexts we discovered seemed to play a crucial role in teachers' *Technological Pedagogical Knowledge* (TPK) development. The discussion in the focus-groups revealed that applied sciences university teachers received important support to their digital competence development from the meso level context, their educational institution. The university of applied sciences offered long-term support in the pedagogical use of technologies by mentoring, in-service training, and investing in technologies designed for pedagogical purposes.

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Quote 2:

> *"We are offered very good chances (for digitalization) in our university. I have had possibilities to work as a teacher online ... I think it's over 20 years now … I mean totally in distance education."*

The macro level context also has an impact. National digitalization policies for education (Higher Education Institute's Digivision 2030) offer a vision, guidelines, and resources for HE institutions in fostering digitalization and improving teachers' digital skills.

Digital disruption of bioeconomy challenges teachers' Technological Content Knowledge (TCK)

The interviewees in our study connected the meaning of digitalization strongly to the on-going digital transformation of their discipline; the application of digital technologies and digitalized data in the bioeconomy. In line with the description of Satpute and colleagues (2017), bioeconomy teachers were aware that rapidly innovative technologies offer many new possibilities for data-driven knowledge creation in the bioeconomy, for example, in the production of renewable biological resources and their conversion into food, feed, and bio-based products. They also mentioned digital monitoring and data flow systems, digital networks and supply chains, and social media as examples of current digital disruption in their discipline.

Quote 3:

> *"If I think (digitalization) on my own subject area, I would mention geographical information systems and management of different applications. Collecting geographical information, digital data gathering and sharing, and data flows. For instance, in different phases of forestry … from the woods to the factories to the ready-made products."*

Although applied sciences teachers' perceptions of digitalization in pedagogy were quite positive, one common view amongst the interviewees in relation to digitalization in their field or in the industry was slightly worrisome. They expressed their concerns, that there will soon be an urgent need to update not only their *Content Knowledge* (CK), but especially their *Technological Content Knowledge* (TCK), due to the rapid digital disruption in the bioeconomy.

The discussion of this theme echoed that digitalization in the bioeconomy has a strong impact on both teachers' CK and TCK, and that these two cannot be separated. Instead, they are intertwined because technology-enhanced working methods are in a complex interaction with content of the bioeconomy. Accordingly, Koehler and colleagues (2013) also highlight that:

> *"technology and content knowledge have a deep historical relationship. Progress in fields as diverse as medicine, history, archeology, and physics have coincided with the development of new technologies that afford the representation and manipulation of data in new and fruitful ways. Consider Roentgen's discovery of X-rays or the technique of carbon-14 dating and the influence of these technologies in the fields of medicine and archeology. Consider also how the advent of the digital computer changed the nature of physics and mathematics and placed a greater emphasis on the role of simulation in understanding phenomena".*

Many of the interviewees speculated that applied sciences university teachers may have quite limited opportunities for updating their discipline's CK and TCK during the rapid changes. When the teachers were asked how they currently develop their substantial knowledge, they described several proactive methods related mainly to informal activities, like knowledge sharing with colleagues and following research and development in the field and relevant businesses. Despite these initiatives, the interviewees seemed to wish for a more systematic and strategic approach, along with support for continuous development of CK and TCK. A common view amongst the interviewees was that the profession of a bioeconomy teacher is currently in a flux.

The teachers also recognized that their meso level context was positively "nudging" their CK and TCK development. This is because the university had recently chosen smart and sustainable bioeconomy as a strategic emphasis, and founded several RDI-projects on the topic (Ryymin et al., 2020). One applied sciences teacher also highlighted the importance of the micro level context for developing teachers' knowledge, as teachers may learn from their students, for example, via project-based learning and in shared problem-solving.

Conclusions

The goal of this paper was to find answers to the following research questions: 1) *What kind of meanings*

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do teachers give to digitalization in their work? and 2) *How does the digitalization of the bioeconomy connect with teachers' Technological Pedagogical Content Knowledge (TPACK)?*

The profession of an applied sciences university teacher in the field of bioeconomy is in a flux due to rapid current digital disruption of the industry. Following the framework of TPACK (Mishra & Koehler, 2006; Koehler et al., 2013), the teachers in this study considered themselves quite competent in their *Technological Pedagogical Knowledge* (TPK), *Pedagogical Knowledge* (PK), and CK related to current (university) curricula. However, they expressed concerns about updating in the near future their CK, and especially their TCK. Despite having many proactive initiatives to update their knowledge, they longed for a more strategic approach to develop their disciplinary knowledge, intertwined with technological innovations. Research, development, and innovation activities, along with stronger partnerships and collaboration with the bioeconomy industry and businesses were mentioned as important activities for teachers in embracing digital disruption. Also, the micro, meso and macro level contexts were deemed as meaningful for applied sciences teachers' development. Positive changes in these contexts may accelerate positive development in teachers' knowledge components. Hence, the strategies of HE institutions play an important role in teachers' knowledge development and adaptation to global changes.

The TPACK-framework states that the core components of teachers' knowledge are in continuous interaction and co-development. Challenges and changes in one core component, sooner or later, effect the other components. Therefore, when supporting teachers to reconcile changes in a disruptive industry, one must pay attention to the co-developing all of the knowledge components. Especially, teachers should have strategies and approaches to develop systematically their *Content Knowledge* (CK) and *Technological Content Knowledge* (TCK) as related to their rapidly transforming discipline.

An applied sciences university teacher can become an agent of change by systematized development, as suggested by Pozos and Torelló (2012). They can commit to generate and share new knowledge in a critical and responsible way. In future research, it will be important to find out what kinds of possibilities and challenges bioeconomy teachers face in their continuous learning and content knowledge development at work. Likewise, questions arise about how to support teachers' development efficiently and optimally during transformations in the digital age.

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References

Amhag, L., Hellström, L. & Stigmar, M. 2019. Teacher Educators' Use of Digital Tools and Needs for Digital Competence in Higher Education. *Journal of Digital Learning in Teacher Education*, 35(4): 203-223. DOI: 10.1080/21532974.2019.1646169

Autor, D., Mindell, D., & Reynolds, E. 2020. The Work of the Future: Building Better Jobs in an Age of Intelligent Machines. *MIT Task Force on the Work of the Future*. https://workofthefuture.mit.edu/wp-content/uploads/2021/01/2020-Final-Report4.pdf

Balafoutis, A., Beck, B., Fountas, S., Vangeyte, J., Van der Wal, T., Soto, I., Gómez-Barbero, M., Barners, A. & Eory, V. 2017. Precision Agriculture Technologies Positively Contributing to GHG Emissions Mitigation, Farm Productivity and Economics. *Sustainability*, 9(8): 1339. DOI: 10.3390/su9081339

Baumüller, H. 2018. The little we know: an exploratory literature review on the utility of mobile phone enabled services for smallholder farmers. *Journal of International Development*, 30(1): 134-154. DOI: doi.org/10.1002/jid.3314

Braun, V. & Clarke, V. 2006. Using thematic analysis in psychology. *Qualitative Research in Psychology*, 3(2): 77. DOI: 10.1191/1478088706qp063oa

Bugge, M.M., Hansen, T., &%Klitkou, A. 2016. What is the bioeconomy? A review of the literature. *Sustainability*, 8(7): 691. %DOI: 10.3390/su8070691%%

Dawkins, M. 2017. Animal welfare and efficient farming: Is conflict inevitable? *Animal Production Science*, 57(2): 201. DOI: 10.1071/AN15383

European Commission. 2012. Communication from the Commission to the European Parliament, the Council, the European Economic and Social Committee and the Committee of the Regions. *Innovating for Sustainable Growth: A Bioeconomy for Europe*. Retrieved January 8, 2021 from: http://ec.europa.eu/research/bioeconomy/pdf/official-strategy_en.pdf

From, J. 2017. Pedagogical Digital Competence — Between Values, Knowledge and Skills. *Higher Education Studies*, 7(2): 43-50. DOI: 10.5539/hes.v7n2p43

Gartner glossary (n.d.). Digital disruption. Retrieved February 1, 2021 from: https://www.gartner.com/en/information-technology/glossary/digital-disruption

Higher Education Institutes Digivision 2030. (n.d.) Retrieved January 8, 2021 from: https://digivisio2030.fi/wp-content/uploads/HEI-Digivision-2030.pdf

Ilomäki, L., Paavola, S., Lakkala, M. & Kantosalo, A. 2016. Digital competence —an emergent boundary concept for policy and educational research. *Education and Information Technologies*, 21(3): 655-679. DOI: 10.1007/s10639-014-9346-4

Ingram, J., & Maye, D. 2020. What Are the Implications of Digitalisation for Agricultural Knowledge? *Frontiers in Sustainable Food Systems*. DOI: 10.3389/fsufs.2020.00066

Kereluik, K., Mishra, P., Fahnoe, C. & Terry, L. 2013. What Knowledge is of Most Worth. *Journal of Digital Learning in Teacher Education*, 29(4): 127-140. DOI: 10.1080/21532974.2013.10784716

Klerkx, L., Jakku, E. & Labarthe, P. 2019. A review of social science on digital agriculture, smart farming and agriculture 4.0: New contributions and a future research agenda. *NJAS - Wageningen Journal of Life Sciences*, 90-91: 100315. DOI: 10.1016/j.njas.2019.100315

Klitkou, A., Bozell, J., Panoutsou, C., Kuhndt, M., Kuusisaari, J. & Beckmann, J.P. 2017. Bioeconomy and digitalization. Background paper. *MISTRA The Swedish Foundation for Strategic Environmental Research*. Retrieved January 8, 2021 from: https://www.mistra.org/wp-content/uploads/2017/12/Bilaga-1-Bakgrundsdokument-Bioeconomy-and-Digitalisation.pdf

Koehler, M.J., Mishra, P. & Cain, W. 2013. What is technological pedagogical content knowledge (TPACK)? *Journal of Education*,193(3): 13-19. DOI:10.1177/002205741319300303

Kyllönen, M. 2020. Teknologian pedagoginen käyttö ja hyväksyminen. Academic dissertation. University of Jyväskylä. Retrieved January 9, 2021 from: http://urn.fi/URN:ISBN:978-951-39-8057-3

Lamberg, L., Ryymin, E. & Vetoshkina, L. Forthcoming. Value Dimensions in Interdisciplinary Research: Facilitating Research Problem Formulation in Smart Bioeconomy. *Manuscript submitted for publication.*

Ministry of the Environment Finland. 2014. The Finnish Bioeconomy Strategy. Retrieved January 8, 2021 from: https://www.biotalous.fi/wp-content/uploads/2014/08/The_Finnish_Bioeconomy_Strategy_110620141.pdf

Mishra, P. & Koehler, M.J. 2006. Technological pedagogical content knowledge: A framework for teacher knowledge. *Teachers College Record*, 108(6): 1017-1054. DOI: 10.1111/j.1467-9620.2006.00684.x

Mulder, M. 2017. A Five-Component Future Competence (5CFC) Model. *The Journal of Agricultural Education and Extension*, 23(2): 99-102. DOI: 10.1080/1389224X.2017.1296533

Perspectives from Higher Education: Applied Sciences University Teachers on the Digitalization of the Bioeconomy

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OECD. 2020. Digitalisation in the bioeconomy: Convergence for the bio-based industries. *The Digitalisation of Science, Technology and Innovation: Key Developments and Policies.* Paris: OECD Publishing.
DOI:10.1787/bd16d851-en

Porras-Hernández, L.H. & Salinas-Amescua, B. 2013. Strengthening TPACK: a broader notion of context and the use of teacher's narratives to reveal knowledge construction. *Journal of Educational Computing Research*, 48(2): 223-244.
DOI: 10.2190/ec.48.2.f

Pozos, K. & Torelló, O. 2012. The Digital Competence as a Cross-Cutting Axis of Higher Education Teachers' Pedagogical Competences in the European Higher Education area. Procedia - Social and Behavioral Sciences, 46: 1112-1116.
DOI: 10.1016/j.sbspro.2012.05.257

Rintala, H., Ryymin, E., Postareff, L. & Lahdenperä, J. Forthcoming. Higher Education Teachers as Continuous Learners: A Mixed Methods Study on Learning Needs and Informal Workplace Learning in a University of Applied Sciences in a Field of Bioeconomy. *Manuscript in preparation.*

Ryymin, E., Lamberg, L., & Pakarinen, A. 2020. How to Digitally Enhance Bioeconomy Collaboration: Multidisciplinary Research Team Ideation for Technology Innovation. *Technology Innovation Management Review*, 10(11): 31-39.
DOI: doi.org/10.22215/timreview/1401

Satpute, S.K., Płaza, G.A., & Banpurkar, A.G. 2017. Biosurfactants' Production from Renewable Natural Resources: Example of Innovative and Smart Technology in Circular Bioeconomy. *Management Systems in Production Engineering*, 25(1): 46-54.
DOI: doi.org/10.1515/mspe-2017-0007

Skog, D.A., Wimelius, H. & Sandberg, J. 2018. Digital Disruption. *Business & Information Systems Engineering*, 60(5): 431-437.
DOI: doi.org/10.1007/s12599-018-0550-4

Stevens, T.M., Aarts, N., Termeer, C.J.A.M. & Dewulf, A. 2016. Social media as a new playing field for the governance of agro-food sustainability. *Current Opinion in Environmental Sustainability*, 18: 99-106.
DOI: /10.1016/j.cosust.2015.11.010

Terry, G., Hayfield, N., Clarke, V. & Braun, V. 2017. Thematic analysis. In Stainton Rogers, W. & Willig, C. (Eds.), *The SAGE Handbook of Qualitative Research in Psychology* (2nd edition), London: SAGE Publications: 17-37.
DOI: /10.4135/9781526405555.n2

Yeates, W.J. 2017. How Good? Ethical Criteria for a "Good Life" for Farm Animals. *Journal of Agricultural and Environmental Ethics*, 30: 23-35.
DOI: /10.1007/s10806-017-9650-2

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http://doi.org/10.22215/timreview/1420

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Simulating a Biorefinery Ecosystem to Manage and Motivate Sustainable Regional Nutrient Circulation

Olli Koskela, Clemens Dempers, Maritta Kymäläinen, Jarkko Nummela

"Finding the right balance between the nutrient abatement objectives and the regulation of adaptive bottom–up solutions is of the utmost importance in solving the nutrient-loading problem."

Antti Iho
Senior Scientist, Natural Resources Institute Finland

Creating an ecologically sustainable circulation of nutrients requires local solutions with commitment from all participating parties. Due to vast differences between various regions, it is very complicated, if not impossible, to create fair, simple, and applicable legislation that can consider all of these differences in a meaningful way. Thus, there is a need for clear and easy ways of developing sustainable and viable solutions locally, as well as communicating them with local community and all the way up to the supervising governmental representatives. To meet this need, we developed a simulation tool that allows the user to explore the effectiveness and impact of a local biorefinery in waste management. As an iterative model based on state machine agents, it can easily be modified for a multitude of scenarios with changes taking place over time, while considering the viewing points of all involved. In this article, we report the first version of this tool and demonstrate its usefulness in estimating suitable biogas reactor size in a biorefinery.

Introduction

Animal husbandry, food production, and soil fertilizing in agriculture all include streams of organic mass that are used in production processes. A large portion of the nutrients of these materials are contained in the secondary outputs, that is, side streams of material, such as manure and industrial side streams. In the interest of more efficient resource usage, it is desirable to collect these nutrients back to circulation with the ecosystem of industries and primary production. Equally important is to be able to manage the distribution of nutrients into the environment in an ecologically sustainable way, that preferably promotes biodiversity also. In addition to the refined nutrient content of outputs, organic mass is suitable for biogas production that can be used in heat and electricity production, and also as transportation fuel.

Local nutrient recycling from waste and side streams managed on a community level would be an effective way of testing the environmental load and controlling the human made impact to the environment. However, due to the number of actors involved at various stages of the agricultural processes, and their sometimes contradicting legislation and personal motivations, current top-down governance slows down the introduction of new technical applications. The paradigm should be shifted to enable the creation of local solutions (Belinskij et al, 2019). One option to increase the understanding of such complex systems is via transdisciplinary computational modeling, where it is possible to include asymmetrical hierarchies between actors and analyze the temporal behavior of the individual actors, as well as the system as a whole (Roodt, 2015; Roodt & Dempers, 2020). Simulation modeling as a form of digital innovation allows the risk-free exploration of different scenarios and business models to facilitate planning and operations. In the work prepared for this paper, we created a first version of a simulation tool to analyze local feedback loops of nutrients and energy through a biorefinery. Our aim was to provide insights to a wicked problem (Pidd, 2010), through building and using a tool to analyze and simulate nutrient streams that depend on multiple variables, as well as to support decision making towards ecologically sustainable and commercially viable solutions.

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The manure management chain consists of activities that safely collect, store, process, and relocate this otherwise problematic material. Biogas is seen as an essential step in this chain and it requires a holistic approach to the whole process (Luostarinen, 2013). Biogas technology was seen in 2013 as the most suitable way to produce energy from manure and cycle its nutrients. Furthermore, biogas plants can be scaled from small household digesters to centralized biogas plants (Luostarinen et al, 2011).

Here, we introduce a biogas reactor and a holistic approach to the wider context with a locally centralized biorefinery that processes waste and side streams from several sources. This biorefinery yields biogas and other re-usable, added-value products, such as nutrient concentrates and biochar. The nutrient outputs of the biorefinery are envisaged to be written into a database that will form the basis for feedback in the loop. Also, we tracked the number of driven kilometers used when transporting the waste from its production source to the biorefinery, thus enabling checks to ensure that the amount of produced energy and value of other products, for example, nutrient concentrates, exceeds the costs of making them. We will refer to this tool with the acronym REBIA: Regional Biorefinery Impact Assessment.

REBIA was designed to allow easy adjustment of waste stream sources and biorefinery locations. The GIS locations of these facilities are specified in an input file. Waste is transported via the road network from its various sources to the biorefinery via routes obtained from the cloud application OpenStreetMap. This is used to calculate transportation costs. In this initial model, we did not constrain the transport fleet thus allowing as many trucks to transport the waste as required. REBIA combines system dynamics and agent-based functionality and can therefore be extended to incorporate a wide range of heuristics and procedures even if no analytic model can be provided. These include, for example, the effect of weather in nutrient distribution in the soil, and different types of production rates and changes. These details will be included at a later stage of our work when the model is extended.

A major use of REBIA is for developing a nutrient circulation business model. Industrial and agricultural companies currently purchase energy, raw materials, fertilizers, and feed, considering this as a separate business process from their waste management operations. Often waste management is also an expense for the business, though exceptions exist where, for example, animal waste can be used to fertilize their own

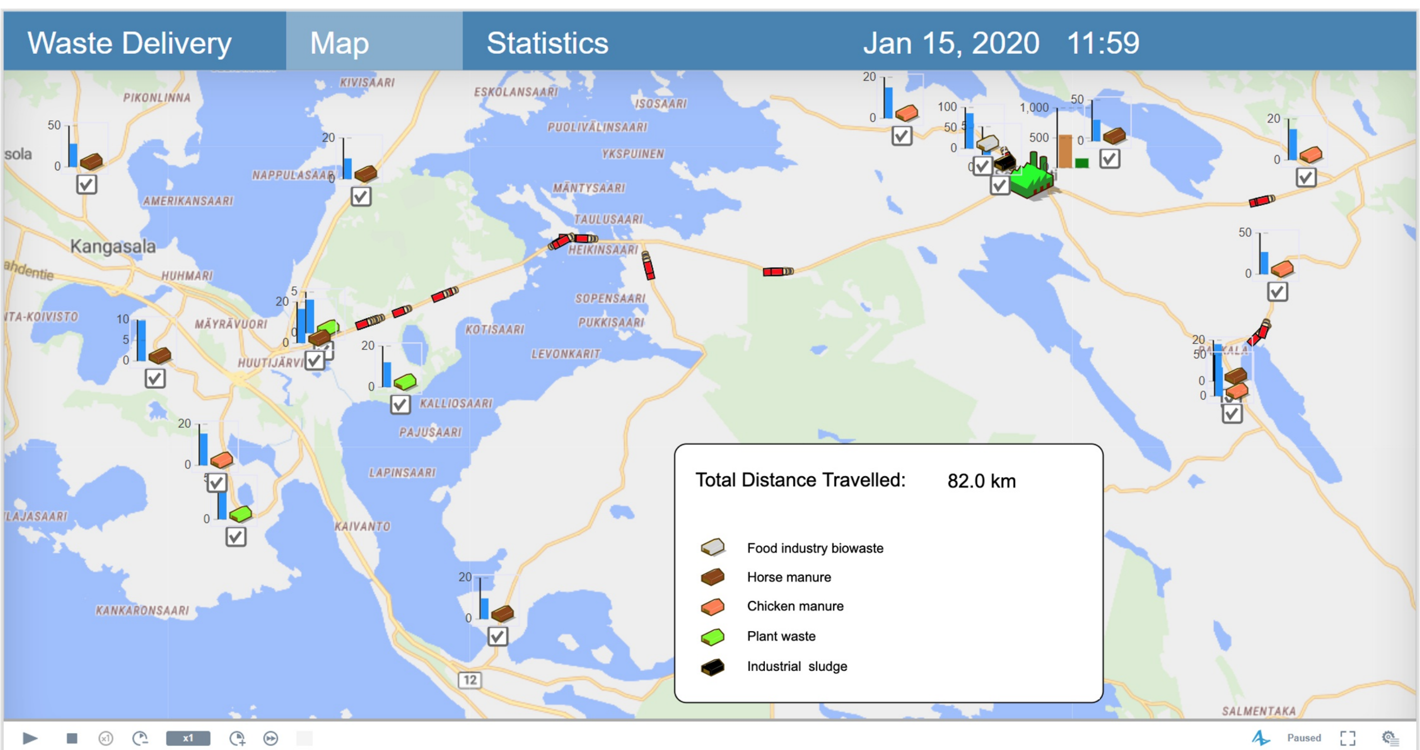

Figure 1. Main view of the simulation interface. Waste collection from sites can be switched on or off, either before or during the simulation run. Optionally, truck visualization can be turned off for faster computation.

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crop fields. The private sector is subject to environmental policies from the government or community. With REBIA, it is possible to analyze the regional circulation of waste, energy, and nutrients in a model where the biorefinery provides new added value to the chain that is missing from traditional processes. Via computational analysis, it is possible to evaluate which regional partners benefit from joining the biorefinery value chain, and whether there are any critical aspects that need to be considered or have a contingency option to ensure safe continuation of the circular economy in this regional collaboration. In addition to this, decision makers of environmental policies can use REBIA to assess if compensation models are beneficial or needed.

In this paper, we describe the details of our first phase REBIA model and demonstrate its usefulness in assessing a bioreactor's size and its required storage volume, as well as the effect of a policy change in a specific manure treatment scenario. We show the simulation results of four experimental cases from the region around the City of Kangasala, Finland. This region provides an interesting area for our research since it contains both a large food industry factory in the countryside and nutrient intensive agriculture. This combination of animal husbandry and a related food industry creates local nutrient load hot spots. Even a small number of these hot spots can generate a significant nutrient load risk to the Baltic Sea. Thus, the management of nutrient streams is important.

Development of the Simulation Tool

REBIA was developed with AnyLogic™ simulation software. Anylogic™ is a Java based multi-paradigm modelling application that incorporates GIS and supports the mixing of System Dynamics, Agent Based, and Process Centric Modelling paradigms. The main view of REBIA is shown in Figure 1, where the waste feed sources and biorefinery locations are shown with a visualization of trucks delivering waste.

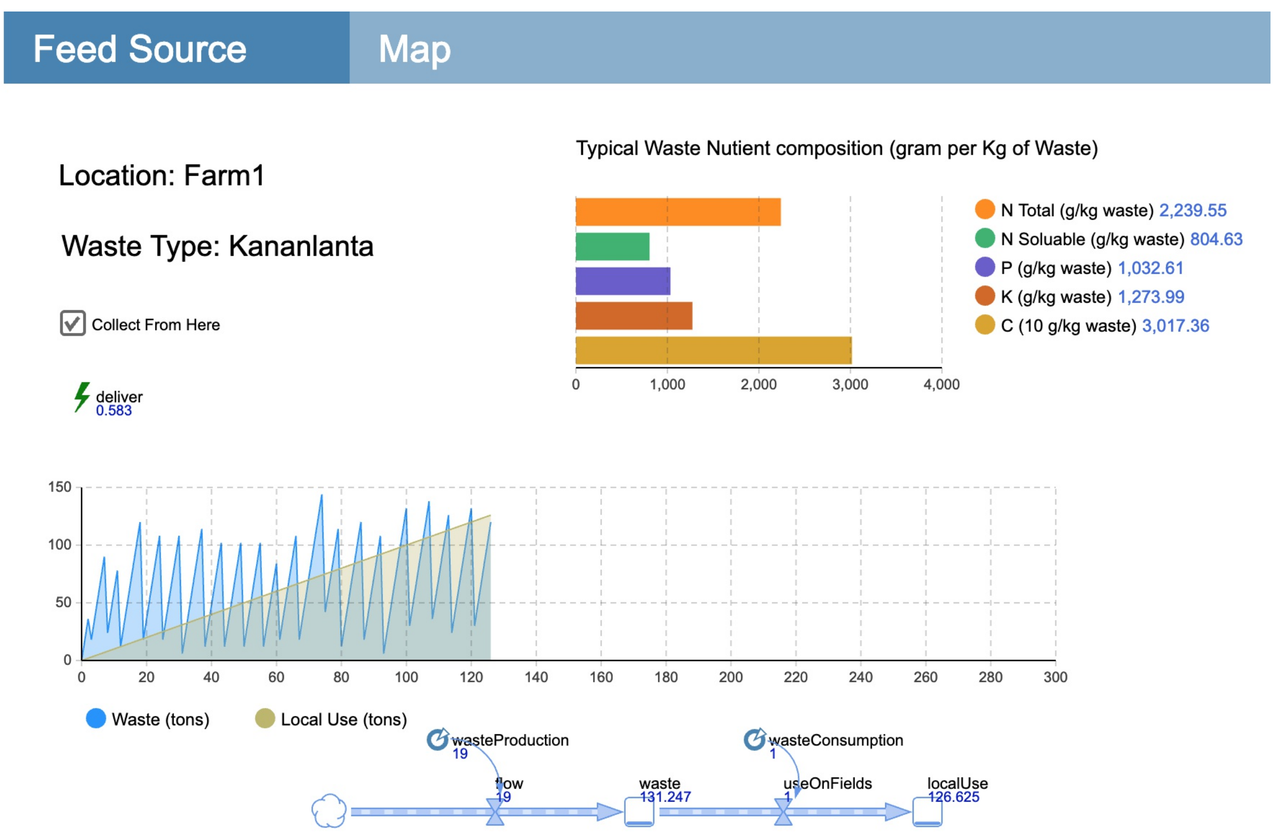

Figure 2. The waste feed source window shows the local waste volume and local use (if applicable to the site) Regular transport to the biorefining plant should keep the average waste on site constant. Typical nutrient components of the feed type are also indicated.

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In this model we identified three main role players that we defined with three agent types: Waste Feed Source, Vehicle, and Bioreactor. Different types of waste are generated at a waste feed source and vehicles transport the waste to the biorefinery, where the waste is converted into commercially valuable products. The model is initialized by an input file from MS Excel that defines the GIS locations and the number and parameters of each waste feed source. This allows easy customization of the model for other areas. It is possible to drill down for more details by clicking on a site to open a detailed view of the internal processes of the feed site (Figure 2). In addition to the adjustable parameters for each agent, the transport vehicle capacity and bioreactor weekly intake volume can be adjusted globally in the initial REBIA implementation.

Waste feed source
We considered five different types of waste streams: industrial sludge, food industry biowaste, horse manure, chicken manure, and plant waste. Each of these waste streams has a characteristic nutrient composition. During model initialization of REBIA, multiple agents are created, each with a different GIS location and belonging to one of the five waste streams. Each site also has a user configurable number of vehicles allocated to it.

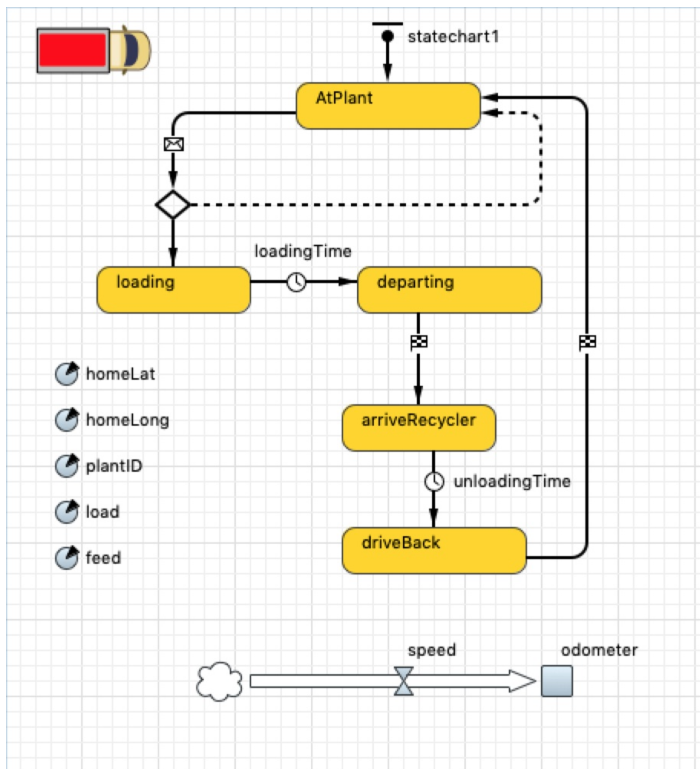

Figure 3. The Vehicle agent contains a state chart that controls its behavior, and parameters that are read or set at runtime.

A system dynamic component calculates waste generation and utilization. Waste is assumed to be created at a constant rate, while some agents also utilize their own waste locally (for example, fertilize crops on the farm). The consumption is modeled with a constant rate, which is much smaller than the waste generation. Waste would therefore accumulate at each source and would then be transported by vehicle to the biorefinery. On average, truck transportation is initiated once per week, provided that more than a truckload of waste is available, and only if the site is active (NB: it is possible to disable deliveries from a site by unticking a selector block).

Vehicle
During model initialization the number of trucks allocated to each waste feed source (termed waste plant in the model) is generated. The vehicle workflow is defined with a state chart and incorporates loading and offloading times. A system dynamic component keeps

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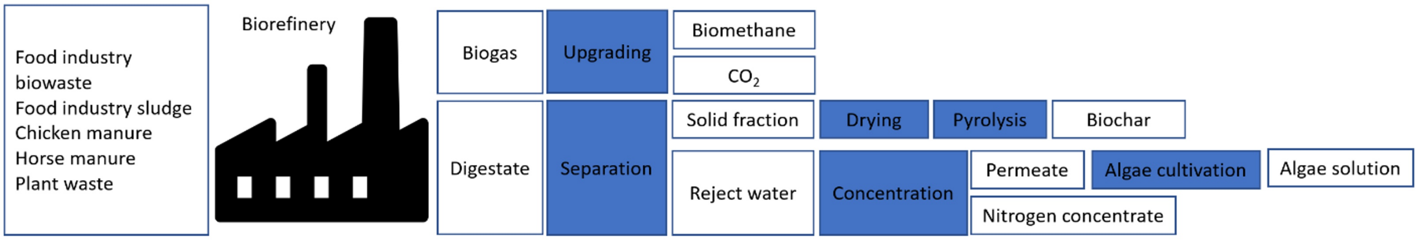

Figure 4. A simplified flow sheet of the biorefinery concept. Material phases are marked with non-filled blocks and process phases with filled blocks. Flows in the image are not based on scale.

track of the distance travelled. The vehicle is assumed to travel at a constant speed of 80km/h on its way to and from the Biorefinery. The loading process is triggered by the arrival of a message generated from the waste plant. Loading will only commence if the amount of available waste exceeds the loading capacity of the vehicle. Vehicle agent state chart is shown in Figure 3.

Biorefinery

The above-mentioned waste materials - manures, plant waste, food industry sludge, and biowaste - are all bio-based raw materials for the local biorefinery. In this study, the materials were upgraded in the biorefinery via several processes for nutrient, carbon and energy rich products, as summarized in Figure 4. The main part of the biorefinery is a biogas plant based on anaerobic digestion of feed materials that result in the production of biogas and digestate. The amount of biogas, its methane concentration, and energy value, are calculated based on experimental data from the specific gas production potential of each feed material obtained by the AMPTS® (Automatic Methane Potential Test

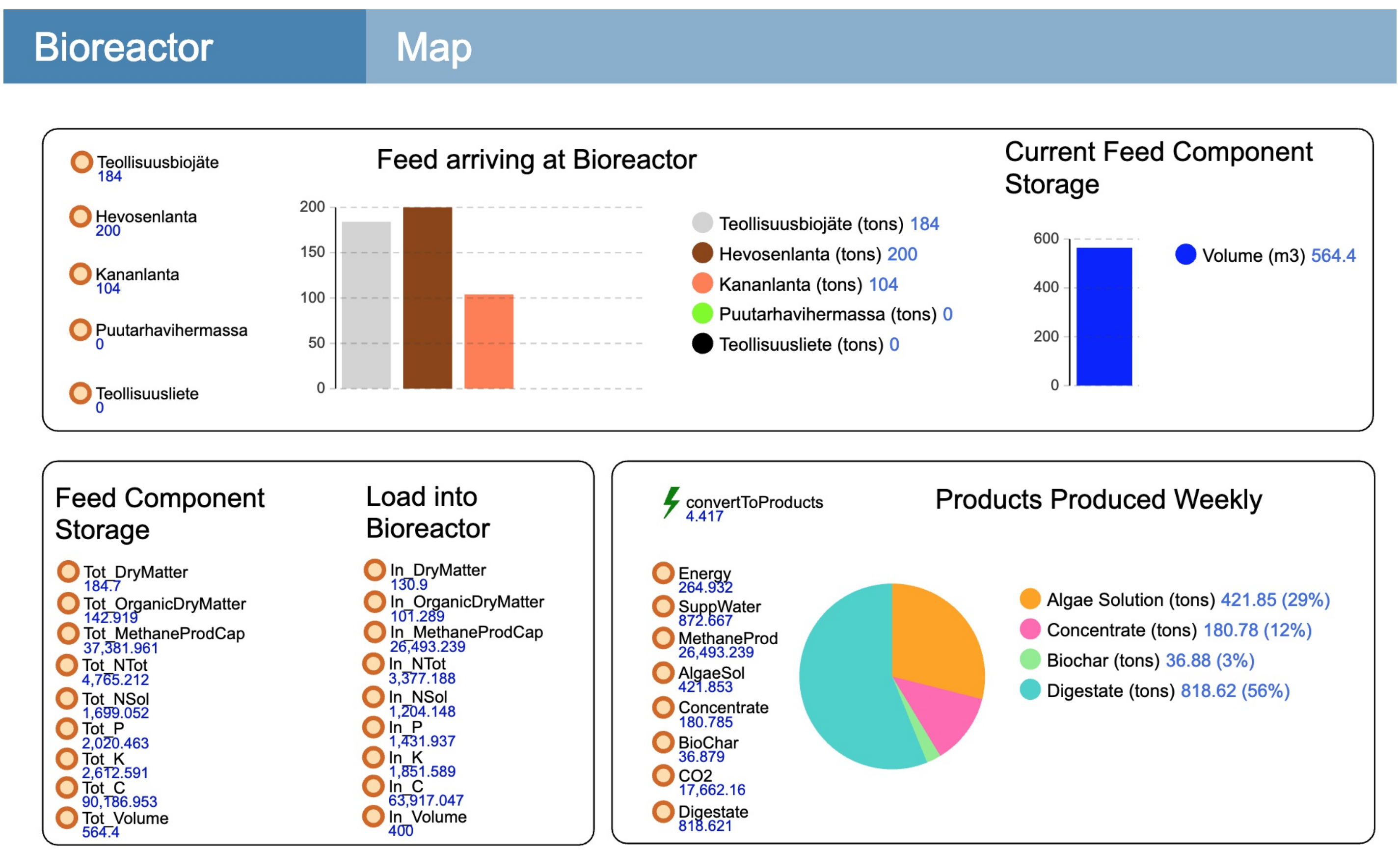

Figure 5. The biorefinery model view contains the cumulative amounts from all sites by waste feed category and the total volume of the stockpile. A chart summarizes the value manufactured products.

System) (Bioprocess Control, n.d.). All the nutrients from the feed materials remain in the digestate, which is separated into a solid fraction and a liquid phase, that produces reject water. The dissolved nutrients, like most of the nitrogen, are in the reject water, which is concentrated by membrane filtration resulting in a nitrogen rich concentrate and permeate. The nutrients in the permeate are further utilized for cultivating microalgae. A solid fraction of about 30% of the dry solid content obtained in the separation is dried before the pyrolysis, meaning the production of biochar. The mass flows of carbon and nutrients along with the total mass flows are calculated based on experimental data from the sub-processes under steady-state conditions.

The internal processes of a biorefinery are calculated with an analytical model implemented in Microsoft Excel (Microsoft Excel for Office 365 MSO 16.0 64 bit). Excel performs mass flow calculations where the biorefinery is assumed to perform in steady state where we assume that there are no transient states between changes of input feed composition nor when initializing the processing plant. We have made a static analysis that input streams to the biorefinery are suitable for processes when there are no major changes in the input. REBIA can be developed further to allow reacting to non-ideal input, for example, by having a buffer of nutrients to mix into the composition, or by running the biorefinery at a lower performance level. Ideally, the static MS Excel model should be replaced by a dynamic model of biorefineries, including feedback loops and dynamic behavior based on examples of changes in feed composition and process temperature.

REBIA uses the biorefinery model to transform waste into a value stream of energy and nutrients based on waste infeeds. It does so by stockpiling incoming waste shipments and then feeding the waste into its reactor at a constant rate. REBIA incorporates a summary view that displays the arrival of waste, stockpile, and processed material at the plant, as shown in Figure 5. The Excel implementation of the model is effectively used as a function to calculate these values, which is accomplished by writing to Excel's input cells and then calculating and reading nutrient values from output cells. The model collects daily activities into a table and

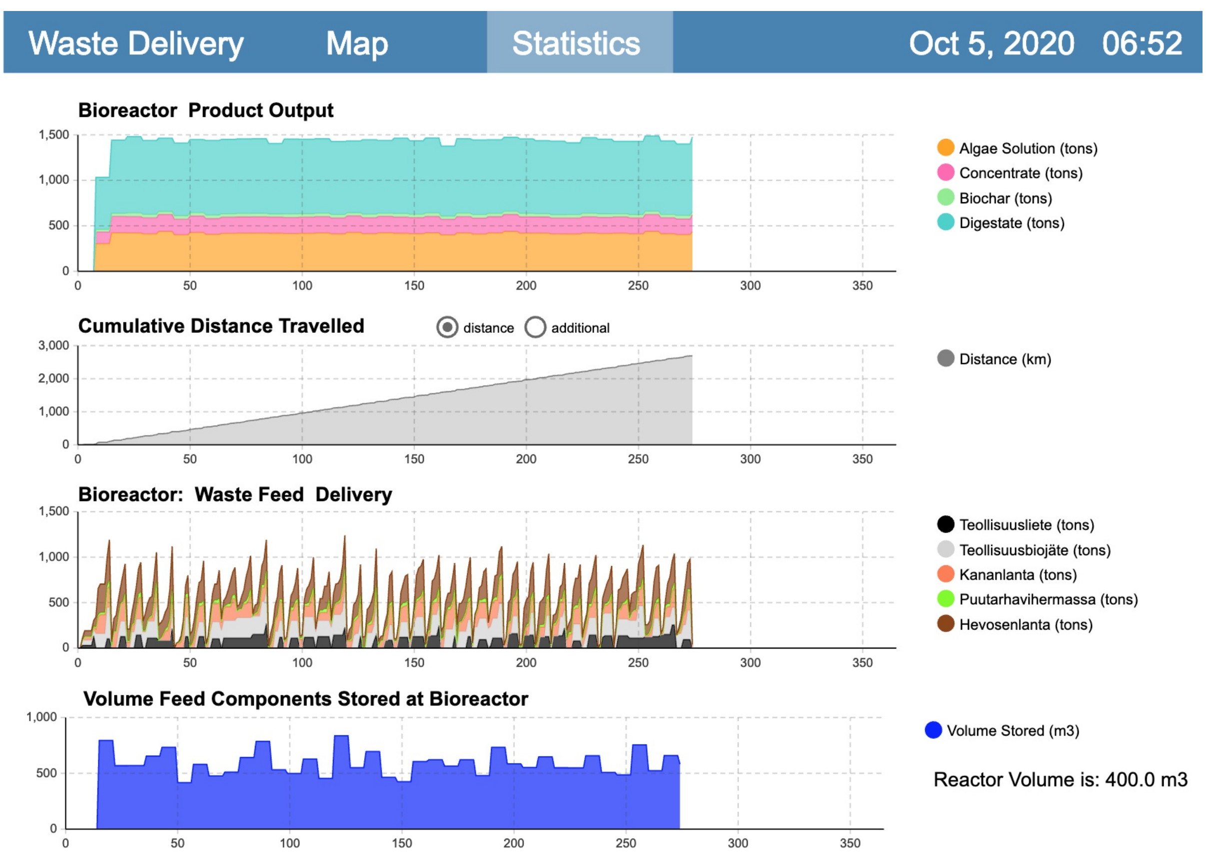

Figure 6. Statistics view. Main parameters of the system are collected into single view that can be exported to a spreadsheet for further analysis. The charts are set to display data that simulates one year.

provides a statistics view, as shown in Figure 6.

Simulation Experiments

To demonstrate REBIA's performance, we report four experimental simulation cases. The first two simulation experiments were both run for a 10-year period and all the waste stream locations were active. Experiment 1 and Experiment 2 only differed in the capacity of the transport vehicles and the process intake capacity of the biorefinery. In Experiment 1, the vehicles were eight-ton trucks and the biorefinery was able to process 400 m^3 of waste per week. In Experiment 2, the trucks were twelve-ton trucks and the biorefinery was able to process 500 m^3 of waste per week.

In Experiments 3 and 4, truck and biorefinery sizes were as in Experiments 1 and 2 respectively, while the experiments were also run over 10 years. After the first three years, collection from horse sites was discontinued. These experiments simulated the case of, say, changes in regulations that horse manure must be transported elsewhere, or the discovery of a new technical innovation that allows more cost-efficient local use of horse manure.

When comparing experiments, the amount of kilometers driven in Experiment 2, 24,290 km, was less over the study period than Experiment 1, 36,450 km. This was expected as the truck size was bigger in Experiment 2. Also, as seen in the histogram from Figure 7, the average amount of feed waste stored at the biorefinery stockpile was less in Experiment 2 at 485 m^3, compared with 584 m^3 in Experiment 1.

In Experiments 3 and 4, by removing horse manure sites after year 3 from input feed production, the kilometers driven over the whole period decreased to 19,055 km and 12,696 km, respectively. The output of the biorefineries in Figure 8 shows a slightly higher product output for these experiments after year 3. This may be attributed to the change in composition of the waste infeed into the reactor, though since transient states were not modeled, the change may not be accurate. The average feed waste stockpile decreased from 349.6 to 250.7 m^3. Examining the histograms in Figure 8, it is clear there were several occasions where the stockpile was depleted. Thus, it is possible to see how the REBIA tool can be used to determine the minimum stockpile size, while maintaining a safety margin.

Conclusion

The strength of REBIA as a type of agent-based simulation is its easy applicability in viewing regional development from different perspectives. Since it

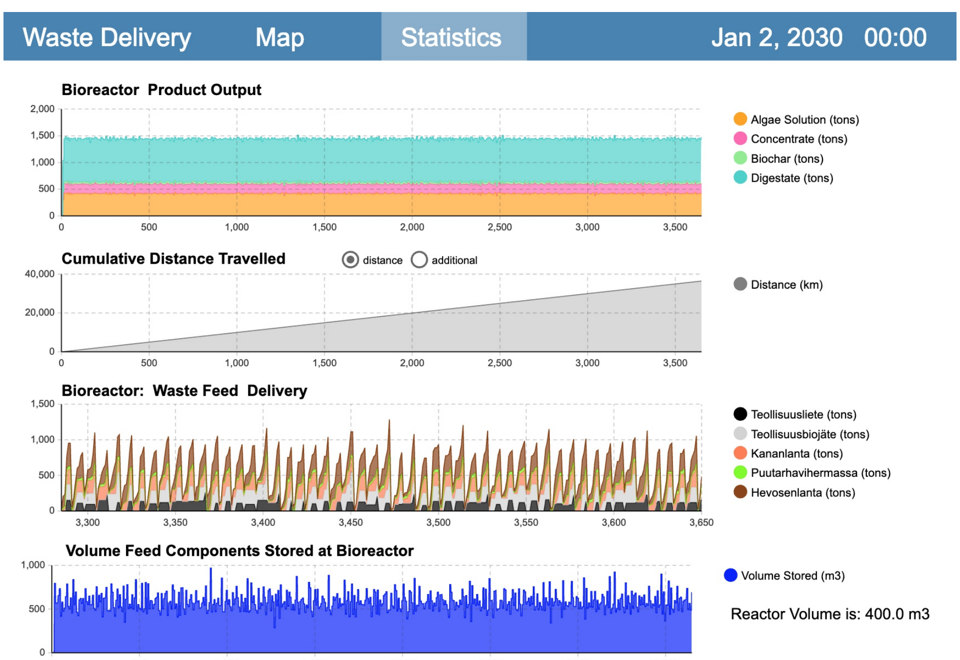

Figure 7. The Statistics view of outputs from Experiments 1 and 2, and a histogram of the weekly volumes of stockpile storage.

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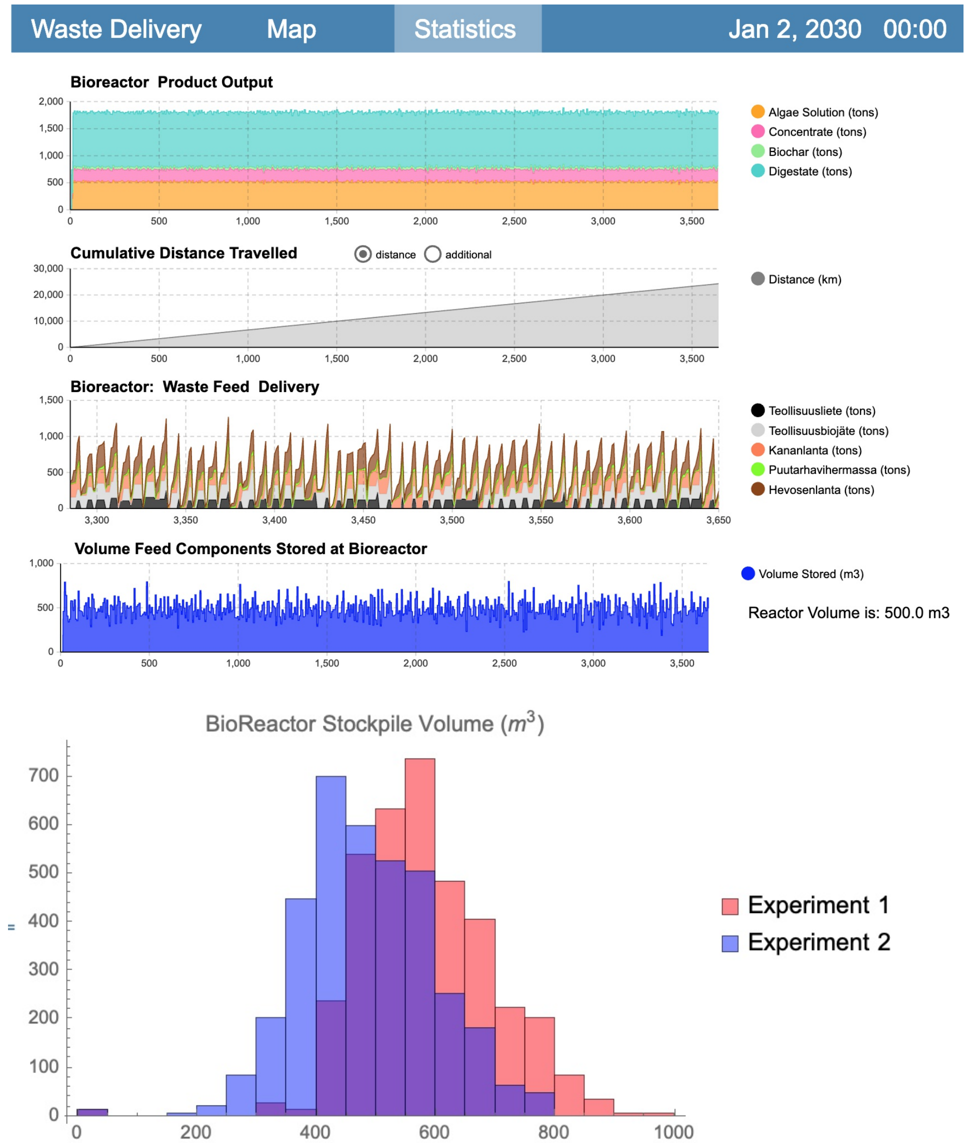

Figure 7. (Cont'd) The Statistics view of outputs from Experiments 1 and 2, and a histogram of the weekly volumes of stockpile storage.

considers the regional ecosystem as a whole, it allows agents configured to make business decisions from their individual perspectives, and then simulating and testing the effect of these decisions to the rest of the ecosystems. This is an extremely important feature, as a community can perform better when everybody has something to gain, that is not a zero-sum game with winners and losers.

With our simulation, it was possible to pinpoint problems on the individual level and create solutions towards win-win situations, such as creating new sellable products (compensation mechanisms), or subsidiaries for an action that has overall benefits in decreased costs elsewhere. Similar aims with different approaches have also been studied in UNISECO project (UNISECO, n.d.), where solutions to environmental problems are being developed bottom-up, from the grass-roots level towards the policy makers, rather than the other way around as has been the case in the conventional approach.

Future development for this simulation tool includes work on optimizing transport (frequency and vehicle capacity) and optimizing the storage location with respect to transport capacity and biorefinery

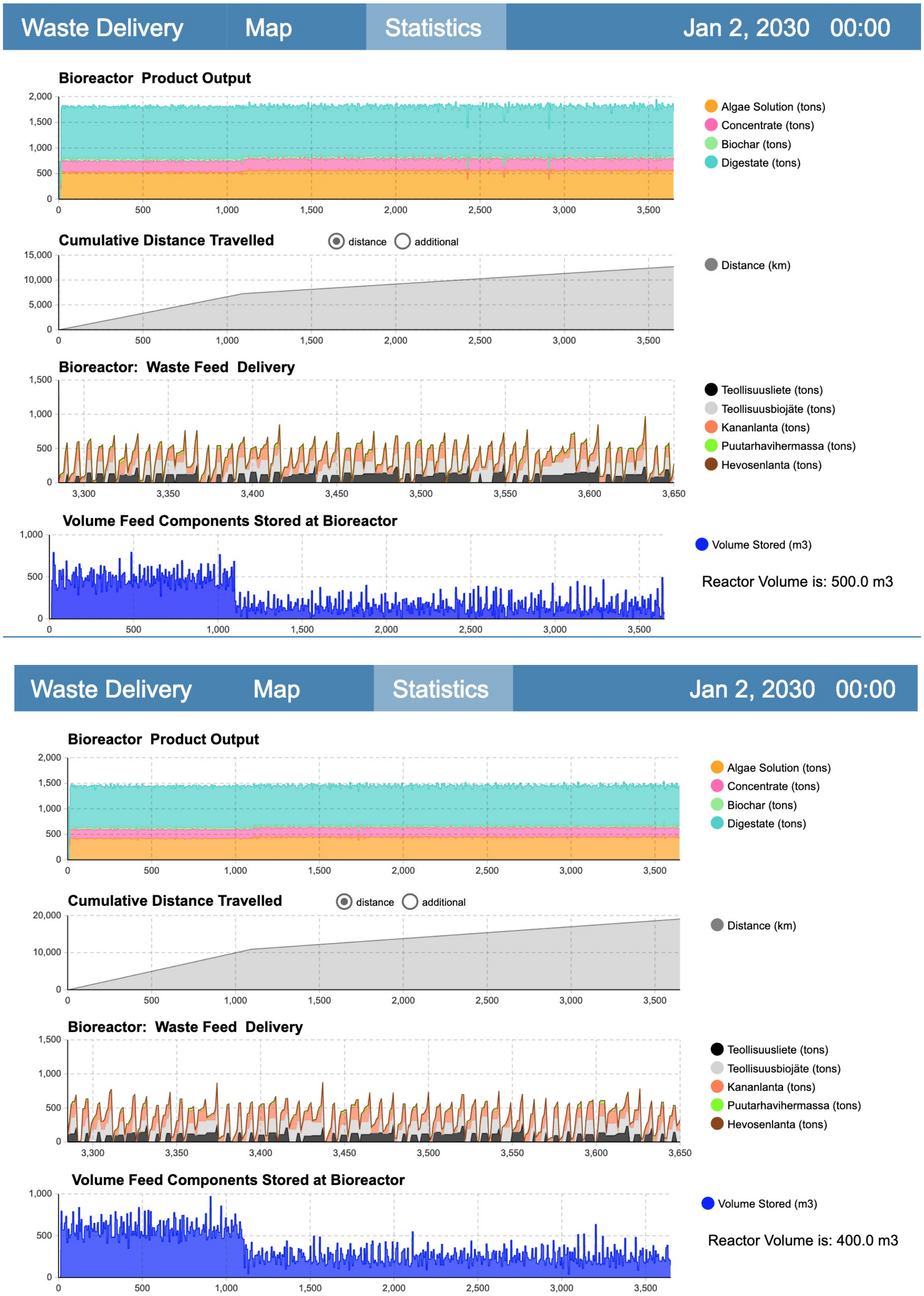

Figure 8. The Statistics view of outputs from Experiments 3 and 4, and a histogram of the weekly volumes of stockpile storage.

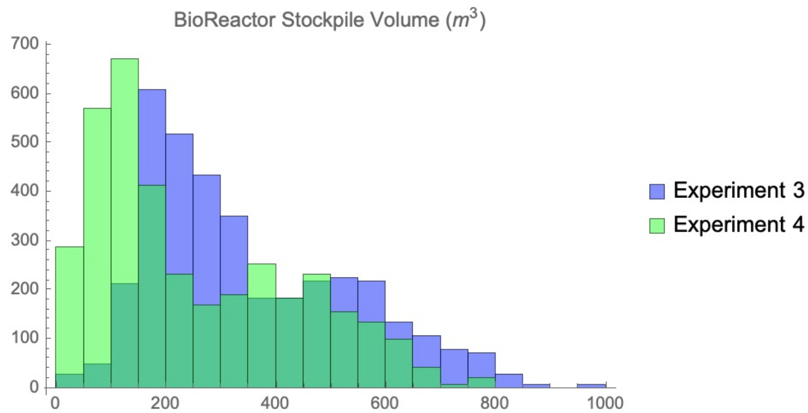

Figure 8. (Cont'd) The Statistics view of outputs from Experiments 3 and 4, and a histogram of the weekly volumes of stockpile storage.

performance, via a push vs. pull business rule. That is, the tool's current implementation schedules deliveries according to the waste source schedule. An alternative is to place an order for the type and volume that the reactor requires. This feature will also have an impact on stockpile requirements.

REBIA is specifically designed to allow easy modification and scaling to any desired region. It can be used to determine where a biorefinery should be located, the quantity of waste involved, and the distance to waste stream sources. Through analysis of the data it provides through regular usage it is designed to help decision making from local actors to governmental supervisors and create motivation in the community around the whole refinery chain, where the actions are considered as moving towards both ecologically and economically sustainable.

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References

Belinskij, A., Iho, A., Paloniitty, T. and Soininen, N. 2019. From Top–Down Regulation to Bottom–Up Solutions: Reconfiguring Governance of Agricultural Nutrient Loading to Waters. *Sustainability*, 11(19): 5364. DOI: doi.org/10.3390/su11195364

Bioprocess Control (n.d.). AMPTS® II. Automatic Methane Potential Test System. Retrieved January 2021: https://bioprocesscontrol.com/bpc_products/ampts-ii/

Luostarinen, S. 2013. National scenarios, best practices and recommendations for manure energy use in the Baltic Sea Region. *Baltic forum for innovative technologies for sustainable manure management.*

Luostarinen, S., Normak, A., and Edström, M. 2011. Overview of Biogas Technology. *Baltic manure WP6 Energy potentials*, 47.

Pidd, M. 2010. Why modelling and model use matter. *Journal of the Operational Research Society*, 61(1): 14-24. DOI: doi.org/10.1057/jors.2009.141

Roodt, J.H., and Dempers, C. 2020. Addressing Challenges of the Circular Economy using Model-Based Co-Creation and Systems Design. *INCOSE International symposium*, 30(1): 94-108. DOI: doi.org/10.1002/j.2334-5837.2020.00710.x

Roodt, H. 2015. The Recursively Generative Nature of Complex Agri-Eco-Socio-Technical Systems: A Transdisciplinary Approach to Developing a Low Carbon Footprint Farming System. *2015 Annual IEEE Systems Conference (SysCon) Proceedings*, 521-526. DOI: 10.1109/SYSCON.2015.7116804

UNISECO (n.d.). Retrieved January 2021: www.uniseco-project.eu

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