Redefining digital bioeconomy

Reviewing how the digital transformation affects gender inequalities in the Nordic bioeconomy

Foreword

Forestry and agriculture, which constitute important parts of the Nordic bioeconomy, are two of the region's most gender-segregated sectors. Digitalisation and increased automation of heavy work could in theory benefit gender equality, this has however not happened. Digitalisation instead risks strengthening the prevailing power structure since information and communication technology (ICT) related university educations and professional groups active in digital technology are also male dominated.

To promote women's influence in the bioeconomy, it is important that they, to the same extent as men, are involved in all stages of the knowledge chain - from education, development and implementation of the new digital technology, to strategic decision-making. To create opportunities for influence and participation in the digital development of the bioeconomy, tomorrow's employees - today's students - need to gain a deeper understanding of the gender imbalance and its implications and be involved in identifying and implementing solutions.

To address the challenges associated with gender imbalance and the digital transformation of the Nordic bioeconomy, Nordic Forest Research (SNS) and Nordic Agri Research (NKJ) have initiated the Nordic collaboration project Bioequality. The project is funded by Nordic Information on Gender (NIKK), Nordic Forest Research (SNS) and Nordic Agri Research (NKJ) and run from September 2020 to December 2021.

This review constitutes the first step in the Bioequality project and will serve as a foundation for informed discussions and decisions for action.

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Summary

The bioeconomy is largely male dominated. Moving towards a digital bioeconomy, the sector is married with the even more heavily male dominated tech-industry. This imposes the question of how the gender balance in the sector will be affected as the digital transformation permeates the bioeconomy. Trying to answer this question, we set out to investigate existing literature on the topic.

While there are plenty of research within the areas of bioeconomy, digitalisation and gender, literature combining all three areas is sparse. This literature review therefore studies the three areas in pairs (gender–bioeconomy/digitalisation–bioeconomy/gender–digitalisation), with the aim of identifying and presenting the most frequent themes within these pairs.

The findings show that:

1) The gender–bioeconomy literature focuses on understanding how the bioeconomy became a field with masculine connotations, symbolically as well as in practice;

2) Within the digitalisation–bioeconomy literature, the most prominent discussions include the use of data analytics, social sustainability, and challenges in adapting to the technologies;

3) The literature on gender–digitalisation raises stereotypes and the masculine construction of technology, education and labour market issues as well as gender equality.

By looking at the intersection of the three areas, analysing the commonalities in the identified themes, two major conclusions are drawn. Firstly, the momentum of the shift in workforce demand both in the bioeconomy and technology sectors could be used to actively redefine the stereotypical bioeconomy worker. Secondly, the need for female leadership, mentors and networks is widely emphasised as key to attract more women to the sectors. With this as a backdrop, we suggested and problematise five action points moving forward:

• Increasing the number of female role models
• Mentorship programs
• Networks for young professionals and students
• Further research in the intersection of digitalisation, bioeconomy, and gender
• Tools and methods to incorporate this topic in bioeconomy-related education

1. Investigating the current state of knowledge on gender in the digital bioeconomy

The bioeconomy is an industry of growing importance for the Nordic economies (Nordic Council of Ministers, 2018). It is also a male dominated industry. The number of women is growing, but the slow growth rate from a low starting point implies the gender imbalance persists. The digital transformation and automation of physical jobs could in theory reduce the gender bias, however, the reverse appears to be true (Larasatie et al., 2020). While digitalisation removes the physical dimension, it requires other non-physical skills and attributes which are also male dominated, such as university degrees in digital technology. Hence, the digital transformation may further entrench the current power structure. A situation calling for action.

So, what do we know about how the digital transformation affects gender inequalities in the Nordic bioeconomy? This review sets out to investigate the current state of knowledge and provide a foundation for informed discussions and decisions for action. While there

Definitions: core concepts

This review focuses on **three complex concepts**; gender, bioeconomy and digitalisation.

● **Gender** is here understood as a socially constructed concept. It means, that beyond biological determinants, notions of gender shape and are shaped by roles, social relations, societal structures, households, and communities (Lorber, 1994). While an intersectional approach to gendered relations (i.e. looking into intersections of class, race, socio-economic background and gender) in the bioeconomy and digitalisation could extend and deepen our understanding of the underpinnings of gendered practices, the study at hand focuses on the most simple and widely used social categories of gender: men and women.

● The **bioeconomy** is an increasingly popular term referring to "parts of the economy that use renewable biological resources from land and sea" (European Commission, 2019). It is often associated with concepts like green economy and circular economy. In this review however, it is primarily interpreted as agriculture and forestry.

● Finally, **digitalisation** is here considered a process of not only comprehensive technical changes, but also social and organisational changes (Rolandsson et al., 2020), encompassing the component of digitisation which refers to the conversion of information from analogue to digital format.
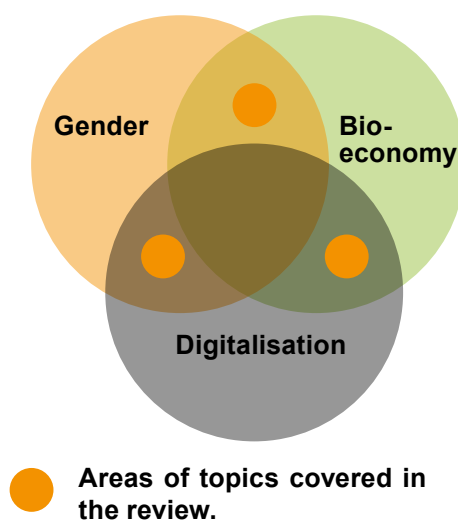
are some recent publications providing examples of gender in relation to a digitalised bioeconomy (e.g. Korsvik's et al. 2020), literature on gender in the digitalised bioeconomy is sparse. By instead studying the three concepts in pairs (gender–bioeconomy, digitalisation–bioeconomy, gender–digitalisation), this review identifies the most frequently studied themes in the literature.

The review first presents literature on gender in the bioeconomy, followed by the digitalisation of the bioeconomy. Thereafter literature on the intersection of digitalisation and gender is examined closer. Within each of the three pairs, the main themes found in the literature are presented. Finally, patterns across the pairs are identified and discussed, and action points moving forward are laid out.

Figure 1: Relationship of the topics covered in the review

● **Areas of topics covered in the review.**

2. A systematic review of the literature on gender, bioeconomy, and digitalisation

This review systematically explores the literature on gender, bioeconomy, and digitalisation. The concepts were studied in pairs (gender – bioeconomy, digitalisation – bioeconomy, gender – digitalisation) and each of the three pairs was reviewed using the same procedure. Google Scholar and Web of Science were selected as search engines due to their wide coverage of literature and quality assurance. Furthermore, English was chosen as the search language and used as a selection criterion implying only articles in English were reviewed. While this excludes potentially interesting literature in the other languages (primarily the Nordic languages) it ensured a stringent approach eliminating any challenges caused by translation. The key words chosen for the three pairs were 'gender bioeconomy', 'digitalisation bioeconomy', and 'gender digitalisation'. Further, since the digital bioeconomy is developing at a fast pace only recent articles were deemed relevant and searches were limited to literature published between 2015 and 2020. For the two pairs concerning bioeconomy, searches replacing 'bioeconomy' with 'agriculture' and 'forestry' were included. The searches generated numerous results from all over the world, articles focusing on areas outside of the Nordics and North American were however to a large extent excluded. This decision was based on essentially two reasons. Firstly, as the study at hand deals with issues in the Nordic countries, preference was given to geographical settings

where greater similarities can be found in nature and organisational structures within forestry and agriculture. Secondly, it was assumed that the gender equality concerns and questions are more relatable and have greater commonalities in the above-mentioned geographical contexts.

A list was compiled of literature fulfilling the criteria, including peer-reviewed, academic literature along with 'grey' literature such as policy and industry reports. Each literature item was subsequently reviewed and categorised with one or several themes. Using this process, the items were ranked from one to three on relevance to the topic studied (one being the most relevant), and this ranking was later used to identify the most pertinent literature. Furthermore, a snowballing method of reference tracking was applied, identifying relevant reference articles in the literature originally gathered. The process described above yielded some 50 to 100 articles per pair, which allowed three to four of most widely recognised themes to be identified.

3. Gender within the bioeconomy

For several decades, gender has been an interest of academic research in the field of bioeconomy. Since the late 20th century and into the 21st, studies have covered aspects ranging from the perception of forestry as a masculine industry to the gendered structures that underpin the bioeconomy. As the bioeconomy becomes increasingly important for sustainable economic development, understanding gender aspects in it is crucial.

This chapter of the literature review is divided into three sections. Firstly, exploring how gender issues in the bioeconomy shapes practices in everyday work. Secondly, looking into why gender imbalances prevail in the bioeconomy, and how current structures affect gender inequalities. Finally, examining how studies on the relationship between sustainability, economic growth, and gender view gender equality as an economic opportunity and as an issue of social justice. The themes are not exclusive, but rather mutually constitutive and overlapping. It can be argued gender in practice has been shaped by socio-historical processes whereby bioeconomy (mainly forestry) came to be seen as a masculine industry. Today, this socio-historical process operates in the structures maintaining high gender imbalance in bioeconomy, especially in leadership positions. Due to this inequality, growth potential is limited, and the economic and social outcomes and opportunities are not equally distributed – thus not making bioeconomy socially sustainable (Hasenheit et al., 2016).

Looking at the Nordic and North American literature in English, most studies on gender and bioeconomy concerns forestry and very few focuses on agriculture. This is reflected in the following sections where bioeconomy primarily is interpreted as forestry.

3.1 How forestry came to be seen as a masculine field

A gendered history of bioeconomy

While the share of women studying forestry and the number of female forest owners is growing, women remain underrepresented in the labour force (SNS, 2020). To start understanding this

situation, this section examines the history of gender issues in the bioeconomy and what kind of practical everyday implications gender has in the bioeconomy today. As mentioned above, forestry has traditionally been seen as a masculine industry (Johansson & Ringblom, 2017; Östlund et al., 2020). Studies from the early 2000s and before have focused on understanding the history and development of masculinities in forestry. During the pre-industrial era, women and men commonly shared agriculture and forestry duties. With increasing mechanisation of the work, traditional feminine duties became masculine, as working with machines and technology were considered more suitable for men (Heggem, 2014). Yet, narratives about agriculture and forestry are often centred on a storyline describing masculinism in forestry as an outcome of a natural process. Research has, for example, focused on how young male workers were recruited to physically demanding timber work in the second half of nineteenth century (Östlund et al., 2020). This narrative has been prevalent in not only constituting forestry as a masculine field but directing research to understand it as a masculine practice. However, recent historical studies have aimed to understand women's early contributions in forestry, diversifying the historical notion of forestry as a masculine field. These studies not only suggest that women have been an important part of different types of forestry works in the history, but also highlight the "narrative of forestry in northern Scandinavia as being an all-male preserve is incorrect. Women have been largely invisible in this narrative --" (Östlund et al., 2020, p. 414). Women have constituted, and continue to constitute, an important part of the labour force in bioeconomy fields, especially in regions where manual labour is still common. In the Nordic countries, digitalisation of forestry further obviates any need

for brute strength. However, it is seen likely that the digitalisation will further exacerbate gender inequalities not because the work is less physically demanding, but because technology, digitalisation and IT are often associated with masculinity. This notion we will explore further later in the literature review.

Gender shapes the perspective of the forestry sector's future

While this masculine narrative still largely prevails in practical labour, women's share in forestry is growing both as forest owners and as students in the field (SNS 2020). Studies have focused on understanding how this prevailing gender segregation in practical labour impact female and male forest owners' approaches to timber and silviculture in practice. Studies have suggested that while there are similarities in how women and men engage in timber and silviculture, differences exist in how female and male forest owners understand and see future opportunities for forestry. For example, a study by Bjärstig and Sténs (2018) examines the way in which male and female forest owners perceive forests and possibilities in the field. The authors conclude that, because of different socio-economic backgrounds, female family forest owners (FFOs) tend to "emphasize health, recreational and environmental factors, such as the conservation of "pristine" nature, to a greater extent than male FFOs" (p. 133). This may in part be due to the fact that women are often less dependent on forest holdings than their male counterparts.

This is especially interesting and important with regards of how forestry could develop in the age of bioeconomy and increasing demand for sustainability. Indeed, studies have argued that female forest owners tend to see business opportunities that are less traditional than male owners. This does however not necessarily imply that women are inherently more ecologically conscious than men, but rather that women could develop other types of "non-traditional" values through forest holdings than men (Umaerus et al., 2019; Häyrinen, 2019).

Gendered practices affect how women and men can gain the necessary experience to work in the field

Studies have also sought to understand how prevailing social structures affect everyday work in the forestry sector. Several forest owners do not notice that there are gendered differences impacting ownership. Nonetheless the work conducted in forests is still largely divided along gender lines (Bergstén et al., 2020). This implies, as later will be explored, that women have more constrained access to opportunities to acquire skills and knowledge needed in forestry, as men mostly carry out the actual work in the forests. This may be a precondition for the differences found in female and male perceptions on forestry as a business. Gendered differences are also evident in ownership, management, and operation due to gender structures (Follo et al., 2016). With this, it is not only important to understand the structures
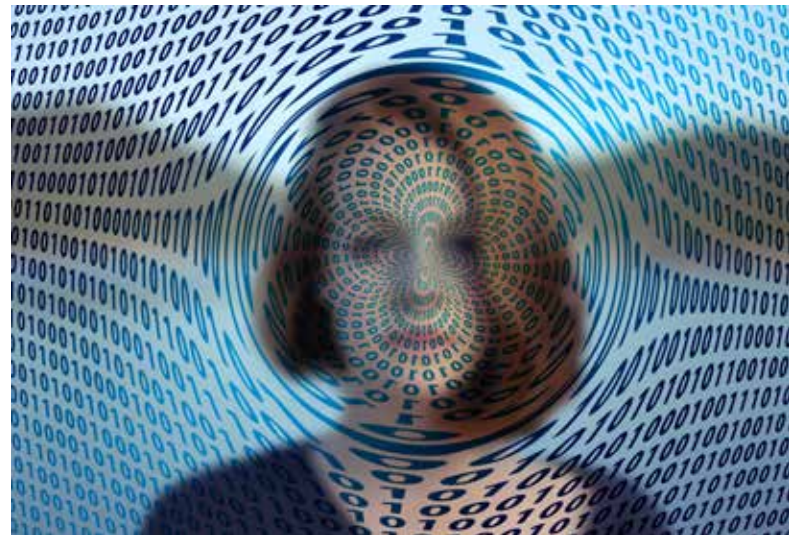
but to ensure representation of different genders (Follo et al., 2016, 182).

3.2 Why are there so few women in the bioeconomy?

Organisational structures and representations halt women's progress

The proportion of females in higher education studying forestry has increased. Yet, this increase has not been reflected in workplaces (Larasatie et al., 2020). Female perceptions of the industry have also been a subject of interest and researchers try to understand how and why women seek employment in forestry (Masiero et al., 2020). Students tend to view forestry as the most important sector in bioeconomy (Masiero et al., 2020). However, female students tend to be less likely to seek employment within the forest sector as the persistence of male representation prevails (Larasatie et al., 2020). Forestry is still "associated with people out in the woods and chopping down trees" -- or "lumberjack stereotype with big bushy beard", holding a "chainsaw", "or fighting fires or working for warehouse or cruising plots"" (Larasatie et al., 2020, p. 419). Such representations of the field leave little room for female "role models" (Larasatie et al., 2020).

In male dominated sectors, women in their early careers often face challenges, ranging from discrimination and exclusion, stereotyping, challenges in balancing work and family life, pay gap and promotion bias (Baublyte 2017; Bardekjian et al., 2019; Andersson & Lidestav, 2016). As with ownership and management, barriers to women's access to networks of knowledge halts career development, maintaining persistent stereotypes that see women as less capable of duties related to forestry (Andersson & Lidestav 2016). Studies also argue that the lack or representation of women may disincentivise women's motivation to enter the field. However, exclusion, stereotyping and inability to balance work and family life, for example, refer to the organisational structures that halt women's inclusion (Baublyte 2017; Masiero et al. 2020; Larasatie et al., 2020).

There are several reasons why women do seek opportunities in the field. For example, respondents to previous studies tend to attribute the choice of desire to work outdoors and to be able to live in the countryside etc. (Larasatie et al., 2020). Yet, according to the study by Bardekjian et al. (2019) up to 84% of women who engaged in the field have experienced barriers at their workplaces due to their gender. This is

partly due to perceptions and representations, but also due to discursive resistance towards gender equality programs (Johansson et al., 2019). Gender equality programs have thus sometimes led to further re-establishment of linkages between competence and masculinity and naturalisation of gender inequality (Johansson et al., 2019). Such continued reinforcing of gender stereotypes in forestry is also visible through experiences of sexual harassment among female students and employees. Sexual harassment and sexist behaviour are pointed out as major barriers for entering and staying in the field (Larasatie et al., 2020; Johansson et al., 2018; Grubbström & Powell, 2020). Such treatment also is seen to re-inforce the gendered stereotype of women being less competent in forestry professions (Johansson et al., 2018).

Increase women's participation through quotas and leadership?

Several studies have debated the best strategy to increase women's involvement in the forestry sector. In terms of process, some have argued in favour of adopting gender quotas in company management, others see quotas as mere 'tokenism' with little substantial impact (Holgersson & Romani, 2020). In terms of impact, some suggest that diversity in leadership positions can have beneficial results for not only company turnouts and competitiveness, but for inclusiveness at the company's organisational culture (Johansson & Ringblom, 2017; Perrault, 2015). Most importantly, diversification of the industry leadership is seen as a strategic premise in order to shift to a more competitive and adaptive bioeconomy (Baublyte et al., 2019).

Yet, on the contrary some studies have shown that having women in high positions do not materialise in more inclusivity. Studies conducted on women's experiences in leadership positions have indicated that women leaders do not see themselves through the gender lens. This means that they may indeed have adapted to the "one of the boys" norm in order to thrive in the field (Baublyte et al., 2019). This indicates that quotas solely may not be sufficient to increase women's representation and participation in the field, because the underlying structures still prevail masculine. Indeed, stakeholder respondents have indicated that despite recruiting women in top leadership positions, industries have not necessarily become more inclusive, because organisational culture lies strongly on masculine norms (Holgersson & Romani 2020; Larasatie et al., 2019). This is evident in company management cultures that revolve around sauna culture or hunting, for example. Other useful approaches to make the industry more inclusive could include sponsorship and mentoring, confidence-building, and inclusive communication strategies, enhancing work-life balance, career planning and tackling sexism and harassment. These strategies aim to make the workplace culture more inclusive, creating support mechanisms for women in a male-dominated field, as well as tackling practical challenges that female workers often face within the

industry (Bardekjian et al., 2019; Johansson et al., 2018).

More representation, networks and mentoring as a way forward
Masculine company and organisational culture often exclude, question and disadvantage women (Johansson et al., 2019). However, the shift towards a service-based forestry and women's own networks could challenge predominant masculine structures and create opportunities for women (Johansson et al., 2019; Andersson & Lidestav, 2019; Laszlo Ambjörnsson, 2019). To conclude, studies identify that promoting women's leadership, sponsorship and mentoring, confidence, communications, work-life balance, career planning and tackling sexism and harassment are all factors that could lower the barriers for women entering the field (Bardekjian et al., 2019; Johansson et al., 2018).

3.3 Can bioeconomy support sustainability if its very structures are not sustainable?

Reaching gender equality creates more opportunities for innovation and enables socially sustainable growth
With increasing demand for sustainability, the Nordic bioeconomy represents a forward-looking alternative to societies built on fossil fuels (Bracco et al. 2018). With growing importance of bioeconomy, gender inequality has important and far-reaching implications in relation to sustainability, social justice and business opportunities (Lidestav et al., 2019; Mattila et al., 2018; Linser & Lier, 2020).

Two major streams of thought can be recognised in the literature on gender, bioeconomy and economic growth. Firstly, as the bioeconomy becomes more important, it will generate an increasing need for employment and innovation (Hansen et al., 2016; Holmgren & Arora-Jonsson, 2015). Some authors emphasise the need to diversify the industry in order to answer the growing need of workforce and to enhance innovations (Holmgren & Arora-Johansson, 2015). This reasoning is strongly linked with the "industrial needs"-argument which sees gender equality in a rather depoliticalized way and treats it as a subject of a managerial practice (Holmgren & Arora-Johansson, 2015; Johansson & Ringblom, 2017). Secondly, the underlying inequalities of the industry can be seen through the prism of social sustainability and justice. Gender inequalities hinder growth and exacerbate the division between "winners and losers". As a male-dominated industry, the increasing importance of the bioeconomy can thus benefit men disproportionally compared to women. (Hasenheit et al., 2016). The arguments following this line of though call for inclusion in order to create and secure socially sustainable development of bioeconomy.
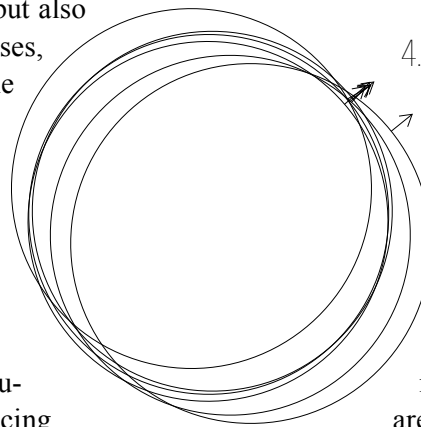
4. Digitalisation of the bioeconomy

Digitalisation is shaping and reshaping society as we know it, and the bioeconomy is not an exception. Bringing digitalisation into the bioe-

conomy via technologies and concepts such as precision farming, big data, automation, sensors, satellite scanning etc. creates new opportunities to satisfy consumers' increasing preferences for eco-consciousness (Watanabe et al., 2019). Taking the forestry industry as an example, the decline in demand for printing paper as a result of digitalisation has led the industry to restructure its business but also develop entirely new businesses, meeting demand for sustainable products, reducing dependency on non-renewable raw materials (Watanabe et al., 2018). Furthermore, digitalisation within agriculture can assist in minimising the environmental impacts of food, meeting consumers demands for locally produced and distributed crops, reducing transportation and ultimately improving sustainability (Raheem, 2020). The current interest in sustainability and the development of a circular economy is hence offering support for the digital transformation of the bioeconomy (Klitkou et al., 2017). Moreover, digitalisation facilitates an increased transparency throughout the value chain, showing where corrective actions are needed and where efficiencies can be gained, working as a means to provide enhanced documentation and shed light on compliance with rules and standards regarding sustainability (Klitkou et al., 2017).

This chapter is divided into three sections presenting themes derived from the analysis of the literature. The first section investigates how the presence and usage of data in the bioeconomy is driving questions of data ownership and governance. The second section examines the social sustainability in light of the digitalised bioeconomy and how farmers stand compared to large corporate actors, and the third section explores the rate of adoption within digitalisation and challenges associated with this process.

4.1 Why data analytics and management are so important

Data analytics is critical for efficient use of data

With the progressive digitalisation of the bioeconomy, concepts such as smart farming, smart agriculture and smart forestry are frequently used terms, emphasising the use of information and communication technology (ICT) in the sectors. Considering the three pillars of smart agriculture - sensors, robotics, and Big Data (Ingram & Maye, 2020), the researchers suggest the data pillar will have the greatest impact moving forward. Sensors, being the technological units collecting large parts of the data, are developing at an increasing pace enabling future cost-effective data collection (Shepherd et al., 2020). The vast amounts of collected data do however need to be managed and analysed to bring value, hence possessing the ability and capacity to conduct these analyses it is key (Ingram and Maye, 2020; Shepherd et al., 2020; Wolfert et al., 2017). This new demand has resulted in the development of new

business models, ventures, and collaborations. As an example, within the area of big data analytics enthusiastic start-ups are seeking to deploy applications for farmers related to sensors, benchmarking, predictive modelling and risk management (Wolfert et al., 2017), bringing analytics services to the farmers and not merely leaving them with raw data.

Ownership of the data determines who reaps the benefits

Looking at this rich data from the perspective of the farmer raises questions about data ownership, control, and reliability. Issues broadly covered in the digitalisation and bioeconomy literature (Regan, 2019; Rotz et al., 2019a; Wolfert et al., 2017). To use the hardware and software produced by commercial machinery actors, farmers are required to agree to certain terms and conditions. However, in doing this they often surrender most rights and inputs as to who controls their data (Rotz et al., 2019a). Wolfert et al. (2017) further highlight that farmers are concerned not only about who benefits from the data, but also about who has access to it. Further highlighting the concern that control of the data often remains with the technology providers rather than the farmers themselves. This raises questions about data governance and Regan (2019) highlights the importance of including the farmers in the process of developing the technologies and governance models, to include their desired benefits from digitalisation. The inclusion of farmers in the development phase is emphasised by Rotz et al. (2019a) as part of discussions of open-source models to ensure the technology and data is owned directly by the farmers, granting them more financial power. Furthermore, to increase collaboration within the bioeconomy, already present examples of free large forestry databases exist. With diverse methods of acquisition and good potential for expansion these databases have great possibilities to develop into complete digital twins of the forest (Klitkou et al., 2017). However, the need for a more open and collaborative data culture between farmers, businesses, researchers, and governmental bodies is pointed out as one of the main challenges in digitalising the bioeconomy (Klitkou et al., 2017).

There is, therefore, a need to focus on and resolve the aspects concerning control and ownership of data. The related privacy and security issues must be appropriately addressed according to Wolfert et al. (2017), with an awareness that too strict application of data rules introduce a risk of slowing down the pace of innovation and adoption.

4.2 Social implications of digitalising the bioeconomy

Technologies tend to benefit major actors on the market

The literature suggests that the digitalising of the bioeconomy – like the digital transformation in many other sectors – leads to some groups benefiting more than others (Rotz et al., 2019b). The technical solutions being developed seem to favour large corporate actors, at the expense of e.g. independent farmers (Rotz et al., 2019a; Finger et al., 2019), not least because affordability of the technology is

an issue for smaller farmers. Within forestry, about 60 percent of Finnish forest resources are privately owned, and in Sweden the corresponding portion of small private owned forests is 50 percent (Klitkou et al., 2017) indicating that affordability may prove to be a large issue here as well. Agricultural technologies such as those for precision farming need to reach large volumes and be widely used to reach their full economic potential (Finger et al., 2019). For the technology to be relevant for small-scale and lower-value crops, there is a need for technologies and business models focusing on other aspects than lowering input costs (Finger et al., 2019). Furthermore, Rose et al. (2020) highlight the concern that private enterprises benefiting from the technologies may lead to increased resistance to uptake these technologies.

Digitalisation affects the labour market and changes the value of knowledge

The literature also raises a concern about what effect digitalisation and surveillance will have on the workforce. Traditional labour hierarchies are increasingly supplanted by technological tools, and the relentless drive for increased efficiency will subject workers in the field to increased surveillance and spiralling expectations of productivity. At the same time, a small number of highly skilled workers will possess the knowledge of how to use digital

technologies to increase productivity (Rotz et al., 2019b). On the same note, Rose et al. (2020) highlight that the increased use of technology may result in the marginalisation of practical knowledge which could ultimately lead to a disconnection between the workers and the landscape. However, Rotz et al. (2019b) also argue that increased digitalisation could benefit these marginalised groups, by increasing transparency within the sector, with favourable effects in terms of labour treatment and fairness. Digitalisation of the bioeconomy is hence associated with significant social implications, both positive and negative. Rose et al. (2020) underline the importance of incorporating social sustainability into the technological trajectories by methods such as outlining a framework favouring multi-actors and co- innovation to ensure sensible socio-technical transitions. Furthermore, as put forward by Rotz et al., (2019b), there is a need to consider what the collective role is in improving the life for the most exposed workers, future possibilities, and livelihoods. If the benefits are not equally shared, Rose et al. (2020) suggest that the potential productivity and environmental benefits enabled by the digital transformation will not achieve their full potential.

4.3 Adoption rates and difficulties in digitalising

Lack of trust for technologies poses a great challenge

The increasing demand for higher efficiency could lead to increased surveillance and unrealistic expectations regarding productivity (Rotz et al., 2019). Furthermore, employing workers who are highly skilled at using digital

technologies might lead to current labour hierarchies being replaced (Rotz et al., 2019). The usefulness of technologies is further questioned along the lines of compatibility with existing farming technologies and routines (Aubert et al., 2012, Knierim et al., 2019). Additionally, farmers are concerned about the level of transparency of data and calculations, resulting in questioning the usefulness of the technologies (Rotz et al., 2019). This lack of trust was found by Shepherd et al. (2020) to be one of the main socio-ethical barriers to the acceptance and use of digital tools within agriculture, these being greater than the actual technological challenges faced.

Market actors not sharing data leads to a broken flow of information in the value chain

Challenges regarding the supply and value chain are discussed in the digital bioeconomy literature. Holmström (2020) highlights that, due to some actors not sharing their data (and having no intention to do so), there is a lack of continuous flow of information within the Swedish forestry industry. This lack of data flow along the value chain leaves the harvesters and market separated, which leads to a decrease in value as the industry becomes disconnected from its customers and the value of their services not being used to their full potential (Holmström, 2020). A system of complete data linkage through the value chain may lead to current business models for agricultural product delivery being challenged (Shepherd et al., 2020). Wolfert et al. (2017) present two extreme alternatives as to how this could unfold, one being a closed system where farmers are highly

integrated in the value chain and the other one being an open collaborative system where all stakeholders have flexibility to choose business partners. Wolfert et al. (2017) underline that the result likely will be variety of the two, depending on e.g. the product, market structure, and setting. However, this will not be revealed until a complete data linkage throughout the value chain is present.

Low digital competence slows down the pace of digitalisation

The low level of digital competence and understanding of its benefits is also discussed from various perspectives in the literature on the digital bioeconomy. Within Swedish forestry this is a critical problem present throughout the value chain where the lack of necessary competence in digitalisation forces a dependence on expertise from outside firms (Holmström, 2020).

Furthermore, experts suggest that while farmers are interested in the value the digital technology brings to their farming, they lack interest in the technology itself (Knierim et al., 2019), which results in low incentives to increase their digital competence. Aubert et al. (2012) further suggest it may not be sufficient to present the farmers with positive outside data on the technologies' economic benefits. Instead, they suggest integrating perceptions of the technology with a given farm's specific characteristics can impact the farmers' adoption decisions to a greater extent (Aubert et al.,2012). Research also show that many farmers thinks it is difficult to identify when and where to invest resources into the digital landscape (Holm-

ström, 2020). This may in part be due to farmers considering a wide range of technological possibilities when investing (Holmström, 2020; Knierim et al., 2019), which makes it time consuming and slowing down the process of digitalising the bioeconomy.

5. Gender perspectives of digitalisation

Digitalisation is one of the many 'megatrends' shaping our society (Sorama, 2018) but it cannot be fully understood without exploring the gender perspective (Dixon et al., 2014). Digitalisation has been described as revolutionising work life and is being presented as 'Industry 4.0'. The entry of 'cyber-physical systems' has resulted in the automation of certain jobs using "autonomously controlled physical entities that make decentralized decisions while communicating with each other in an internet of data and services" (Krzywdzinski et al., 2016, p.22). Koskivaara & Somerkoski (2020) further state that digitalisation is seen as the most powerful tool to change the world, and that no society can afford to create this future digital world under a gender bias.

5.1 Inequality in labour market and education

Digitalisation both enables and disables women's opportunities

While digitalisation is seen to create many opportunities for employment, it can on the other hand exacerbate existing inequalities. Some studies have argued that sectors which traditionally have significant proportions of female workforces are less likely to be affected by digitalisation than male-dominated sectors and women are less likely to benefit from the opportunities. However, some argue manual labour will be most affected by automation. Most of the literature relating to digitalisation and the labour market deals with the opportunities and risks associated with this new world of work (Abrahamsson & Johansson, 2020; Sorgner et al 2017; Brussevichet al. 2018; Peetz & Murray, 2019; Krieger-Boden & Sorgner, 2018; Muro et al., 2017; Poutanen & Kovalainen, 2017). Abrahamsson & Johansson (2020) illustrate this with two possible scenarios: one where digitalisation acts to strengthen existing male domination of industries such as mining, and the other one where it opens the

prospect of undoing gender bias in the industry, emphasising that the later scenario may be too optimistic. Authors highlight existing inequalities may be exacerbated by digitalisation (Johansson et al. 2020), while simultaneously digitalisation creates new labour opportunities (Abrahamsson & Johansson, 2020). For example, it can help women to gain access to labour markets due to increased flexibility (Accenture, 2016; Beliz et al., 2019; Rajahonka & Villman, 2019). With this, many articles also propose solutions and crucial themes for governments to take into consideration to secure equal employment opportunities and work for all.

Digitalisation creates opportunities in STEM fields where women remain a minority

Digitalisation is related to further automation of jobs. According to Sorgner et al. (2017), 40-60% of all jobs in the G20 countries will be affected by digitalisation. Some have argued women's jobs are less likely to be affected than male dominated jobs, as women to a large extent work in households and healthcare sectors (Sorger et al., 2017; Peetz & Murray, 2019). However, most articles conclude that women, more often than men, work in "low-skill clerical, service, and sales positions" and are thus "disproportionately exposed to automation" (Brussevich et al., 2018). Moreover, literature express that women are disadvantaged in accumulating the knowledge needed for digitalised jobs as they, more often than men, are affected by the limited access to child-care and therefore do not have as much time to allocate to learning (and staying up to date with)

emerging technologies and digital tools (De Vuyst & Raeymaeckers, 2019). While women experience greater obstacles in employing digital technologies than men, it is however also acknowledged that when employed, the benefits are evident (Rajahonka & Villman, 2019), encouraging women to continue the adoption of digitalisation.

Another major issue in the labour market is women's underrepresentation in science, technology, engineering and mathematics (STEM), indicating women are generally less likely to be positively affected by increasing digitalisation (Peetz & Murray, 2019; Sorgner et al., 2017; Piasna & Drahokoupil, 2017). Women face difficulties in accessing the field due to stereotypes and social barriers, lack of representation and access to social networks and financial constraints (Sorgner & Krieger-Boden, 2017, Hill et al., 2010). Studies have suggested that governments should create incentives and support women's access to STEM fields through education and bridge the digital gender divide, rather than putting emphasis on women "breaking the glass ceiling" (Sorgner et al., 2017; Sorgner & Krieger-Boden, 2017; Brussevich et al., 2018). Furthermore, creating female-exclusive platforms for knowledge sharing and networking is seen as encouraging and assisting tools to foster women's participation in ICT and STEM industries (Pröbster et al., 2018).

Some studies also highlight increased opportunities for women, as women are considered to have better social and leadership skills, which will play a more crucial role in the age of digitalisation (Krieger-Boden & Sorg-

ner, 2018). However, the main issues hindering women's advancement are understood to be constituted by gender stereotypes and social barriers, especially evident in the ICT field (Peetz & Murray 2019; Krieger-Boden, 2018).

Digitalisation creates a vast array of opportunities for entrepreneurship (Fossen & Sorgner, 2018). However, the structure of work may exacerbate existing inequalities, as women only represent 30% of all entrepreneurs (Kirch & Eisenbart, 2018), and are less likely to receive investments for innovations (e.g. venture capital) as they still to a larger portion continue being responsible for housework and childcare responsibilities (Piasna & Drahokoupil, 2017; Poutanen & Kovalainen, 2017). These factors further limit women's possibilities to participate in the digitalised economy.

Gender imbalances in education discourage future potential female students

One way to promote a more balanced outcome for digitalisation is through education and especially higher education. There is a need for roughly 40 000 new IT experts in the Swedish IT industry (Mozelius, 2018). Women however represent only 25 % of students in the IT sector while more than 50 % of higher education students are women (Mozelius, 2018). These figures are problematic in themselves, but also in terms of what they result in. Examining the ICT education, studies further reveal that more than 75% of supervisors are men and the most common type of discrimination within the education is gender-based (Koskivaara & Somerkoski, 2020). Women's participation

in higher ICT education has widely been encouraged and has been boosted by initiatives such as computing camps for girls (Lee et al., 2015). Participants have highlighted the positive effects of the creation of safe spaces and opportunities to experiment and play with technology (Lee et al., 2015), increasing interest in the area in non-traditional ways. Larsson and Viitaoja (2019) argue that changes in attitudes and behaviours have greater impact than policy and regulation and therefore female role models and promotional campaigns are of greater importance to attract more girls to these areas. However, despite this awareness and active work against imbalances and discriminations in ICT education, the persistent masculine associations have hindered women's enthusiasm to engage themselves in the field (Sorama, 2018).

5.2 Gender constructs and stereotypes portraying the tech-industry as masculine

Technologies and digitalisation are portrayed as masculine

Technologies and opportunities in the digital era are generally considered to be fields intended for men. Studies examined participants' attitudes towards opportunities revealed women often saw technology, data, and digitalisation as masculine fields. That notion hinders women's enthusiasm for entering the field (Sorama, 2018; De Vuyst, 2018; Franken et al., 2018; Schuster & Martiny, 2016), and creates a tendency for women to be less vocal about technology interests and downplaying their competence in the area (De Vuyst & Raeyma-

eckers, 2019). The masculine construction of technology and digitalisation is also present in concrete ways with regards to women's access to knowledge, ability to perform work-related tasks, and in negative stereotyping and harassment (De Vuyst, 2018; Terrell et al., 2017). Gender stereotypes further enforce segregation and negate professionalism (Padovani et al., 2019).

Abrahamsson & Johansson (2020) found that masculinity, in the sense of traditionally masculine forms of work such as mining, is changing as digitalisation is changing the sector. However, it is still believed the male dominance will persist within the sectors and lines of work, albeit in a different manner, due to the ongoing generalised masculine association to technology (Abrahamsson & Johansson, 2020; Johansson et al., 2020). Moreover, literature in the field also emphasis that women face barriers to participate in ICT training at workplaces because of housework responsibilities (Padovani et al., 2019), enlarging the gender gap within digitalisation.

5.3 Digitalisation provide both obstacles and opportunities in addressing gender inequality

Inequalities in the digital industry constrain women
Understanding gender inequalities is ever more important as jobs are becoming increasingly digitalised. Digital industries are traditionally male-dominated fields (Johansson et al., 2017) where inequalities in the digital fields mirror the structural social inequalities present in society (Correa, 2016).

This is indeed reflected as the majority of female students see less opportunities in digitalisation (Franken et al., 2018). If the development of training opportunities for women are not successful, there is a risk that existing inequalities will "continue to reassert themselves" in the workplaces (Piasna & Drahokoupil, 2017; Warmuth & GlockentGlockentöger, 2018). Indeed, when students in ICT educations were interviewed, most female students aspired for a successful career in the IT industry but because of childbearing responsibilities and existing gender stereotypes thought they would be unlikely to achieve their career goals (Pechtelidis et al., 2015).

Digitalisation may favour both men and women
With the present gender inequalities in the digital transformation of industries, it is debated whether men or women stand the most to gain. On one hand, Larsson and Viitaoja (2019) argue that the automation of jobs will affect those traditionally fulfilled by women to a greater extent than those of men.

On the other hand, it is claimed the shift in employment towards occupations with less strict routines and physical work may favour women (Krieger-Boden & Sorgner, 2018; Larsson & Viitaoja, 2019). Along with this, women's superior social skills are increasingly desired in the age of digitalisation, thereby providing women a competitive advantage (Krieger-Boden & Sorgner, 2018). Some aspects of digitalisation have the potential to favour women at the workplace, however they are not many and must be actively supported. If not, there is a risk most of the opportunities associated with digitalisation will disproportionately favour men.

6. Concluding remarks

This review attempts to answer the question of how the gender balance in the bioeconomy will be affected as the digital transformation permeates the sector. To address this question, we turned to the literature reviewing the current state of knowledge on gender, bioeconomy, and digitalisation. Since literature in the intersection of these three concepts is sparse we studied the three pairs (gender – bioeconomy / digitalisation – bioeconomy / gender - digitalisation), with the aim of identifying and presenting the most frequent themes within these pairs. The main findings include:

Gender and bioeconomy

● The gender and bioeconomy literature focuses on understanding how bioeconomy (especially forestry) became male-dominated symbolically as well as in practice
● Studies also demonstrate how the symbolistic masculinity materialises in everyday practices that shape gender imbalance within the sector
● The embodiment of these gender norms exacerbates societal inequalities in the future bio-based societies because women lack access to the bioeconomy professions

Digitalisation and bioeconomy

● Within the digitalisation of the bioeconomy, most prominent discussions include the use of data analytics, the rising issues of data rights and studies on which actors that stand the most

to benefit from this development
● A shift in the preconditions for the workforce in the bioeconomy, along with changing business models and the value of other forms of knowledge than those of traditional farming and forestry is also raised

Digitalisation and gender

● Masculine and feminine stereotypes and the masculine construction of technology is clearly present both in education and on the labour market today
● This is preventing women from further entering the tech and digital industries and tertiary education
● Automation and digitalisation have gender related impacts. Manual work is likely to be replaced by automation, and the demand of labour in coding, innovation and engineering is increasing

Intersecting the three topics

Having studied the three pairs separately, the intersection of the three concepts bioeconomy, digitalisation, and gender was examined resulting in two conclusions (illustrated in Figure 2).

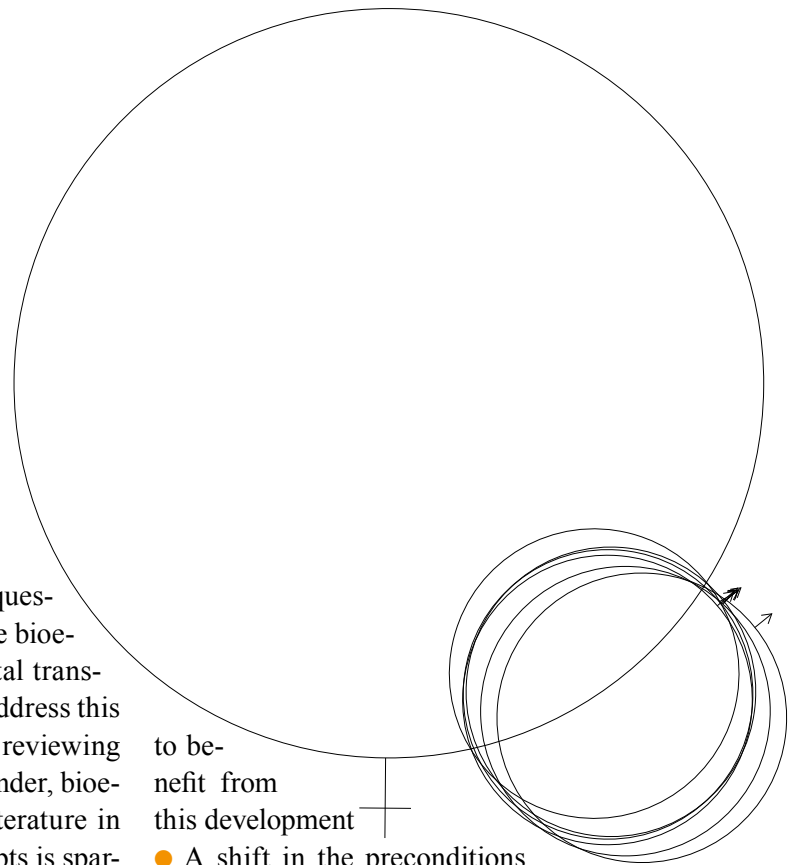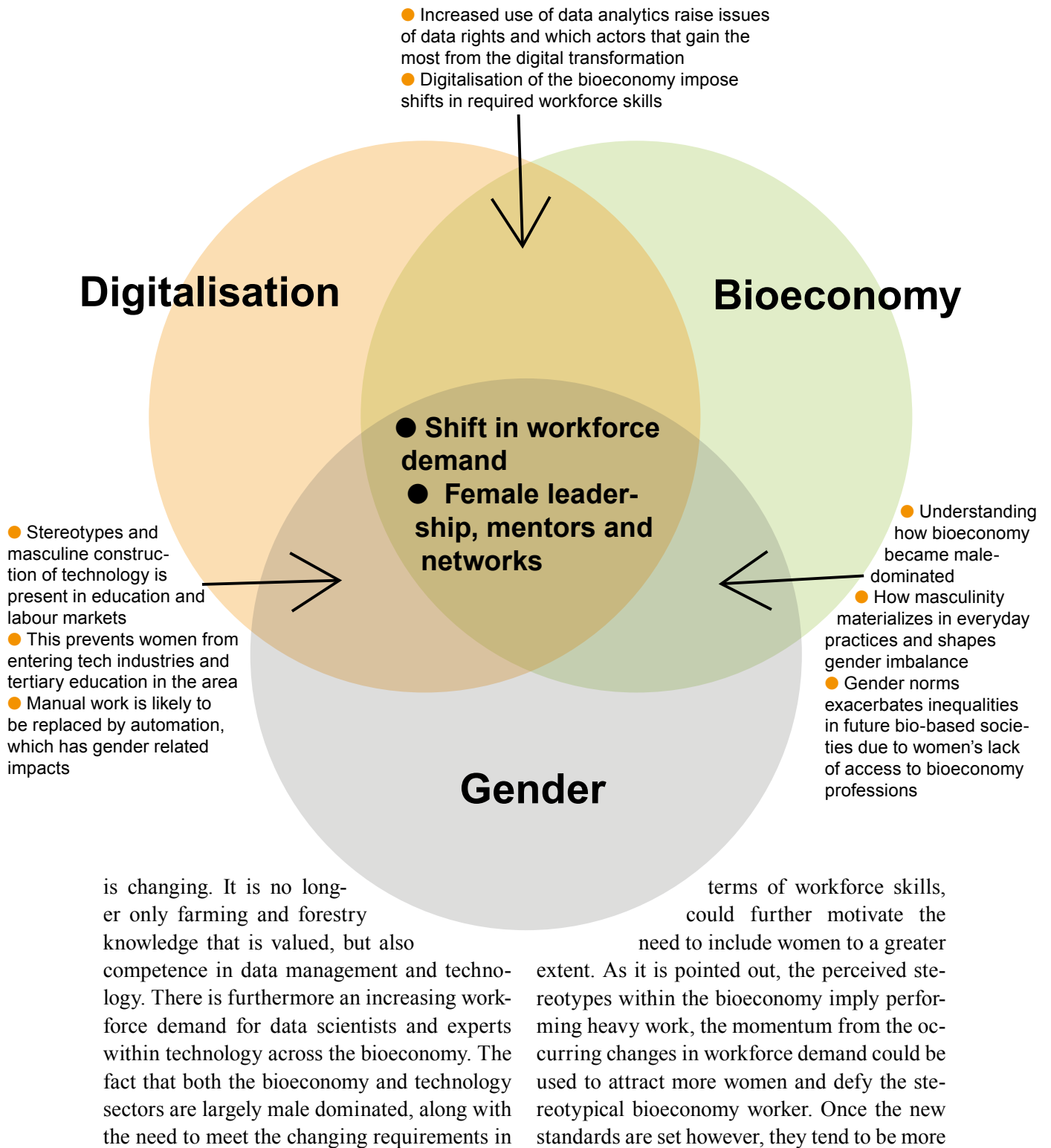Firstly, the workforce in the bioeconomy

Figure 2: Conclusions and their relationships

● Increased use of data analytics raise issues of data rights and which actors that gain the most from the digital transformation
● Digitalisation of the bioeconomy impose shifts in required workforce skills

Digitalisation

Bioeconomy

● **Shift in workforce demand**
● **Female leadership, mentors and networks**

● Stereotypes and masculine construction of technology is present in education and labour markets
● This prevents women from entering tech industries and tertiary education in the area
● Manual work is likely to be replaced by automation, which has gender related impacts

● Understanding how bioeconomy became male-dominated
● How masculinity materializes in everyday practices and shapes gender imbalance
● Gender norms exacerbates inequalities in future bio-based societies due to women's lack of access to bioeconomy professions

Gender

is changing. It is no longer only farming and forestry knowledge that is valued, but also competence in data management and technology. There is furthermore an increasing workforce demand for data scientists and experts within technology across the bioeconomy. The fact that both the bioeconomy and technology sectors are largely male dominated, along with the need to meet the changing requirements in terms of workforce skills, could further motivate the need to include women to a greater extent. As it is pointed out, the perceived stereotypes within the bioeconomy imply performing heavy work, the momentum from the occurring changes in workforce demand could be used to attract more women and defy the stereotypical bioeconomy worker. Once the new standards are set however, they tend to be more

rigid and difficult to change, hence it is key to make advantage of the current momentum.

Secondly, as it is recognized that most workers in technology are men, there is a need for a wider type of rethinking. Literature on both digitalisation and bioeconomy highlight that female leadership, mentorship and networks are required to attract more women to the sectors. What could however be questioned is whether it is fair to add even more activities to women's schedules that do not necessarily contribute to their career advancement. A better understanding of these aspects is needed.

Looking at the future of the digital bioeconomy, it is evident there are both opportunities and obstacles in terms of tackling the gender imbalance. History shows that the more

mechanised the industry, the more it becomes associated with masculinity (Heggem, 2014) exemplifying one of the challenges which needs to be acknowledged and then addressed to ensure an inclusive development of the Nordic bioeconomy. An inclusive and gender balanced bioeconomy is important for several reasons, not the least since innovation and sustainability rely on its internal diversification. According to the studies explored in this review, women's access to tech, bioeconomy, and other male associated domains is still halted by stereotypical image of women and men, of sexist behaviour, of everyday gendered practices and other access issues. To harness its full potential, the Nordic bioeconomy needs to address these issues.

Suggested action points

Increasing the number of female role models and thereby diversifying the masculine image creating more inclusiveness. This action can however at best serve to set an example and encourage women to seek education related to, and employment in, the digital bioeconomy. This alone is not enough considering that the very structures of bioeconomy and tech industries remain masculine.

Mentorship programs can empower young female graduates to pursue careers in the digital bioeconomy. Setting up mentorship programs is however associated with challenges and in need of reflective thinking. It important to remember is that the aim is not change women to be "better" or "more like men", but rather for men and women to be equals. Critical issues to discuss in organizing this is the sex of the mentors and adepts, how the programs should be designed, and what the overall focus should be.

Networks for young professionals and students in the bioeconomy are valuable for strengthening connections, facilitating discussions, and increasing inclusive involvement for students and workers. Peer support is important in succeeding in male dominated industries, where the peer support can come from both men and women.

Pursue further research in the intersection of digitalisation, bioeconomy, and gender as it is today scarce and the need to further understand how the digital transformation affects the gender balance in the bioeconomy is evident.

Develop tools and methods to incorporate this topic in bioeconomy-related university education. The aim being to facilitate a discussion on how gendered structures impact men and women and their opportunities within the fields of digital bioeconomy and thereby create a foundation for change.

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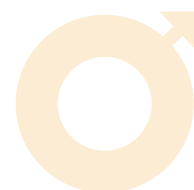
Redefining digital bioeconomy

Reviewing how the digital transformation affects gender inequalities
in the Nordic bioeconomy

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