



Universiteit Utrecht

Research Report:

Biomass Production

Utrechtse Heuvelrug

Regional Integration Project
(GEO1-2416)

Group 1D: Forest management and biomass production

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Word count: 6310



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1. Introduction

In the face of climate change and finite resources, the United Nations have been committed to shape a more sustainable world by defining the challenges that need to be tackled (United Nations, 2021). While global collaboration is required, national and local implementations are equally important. This being so, the Netherlands decided within their climate agreement to reduce its greenhouse gas emissions by 49% compared to the 1990 levels (Dutch National Government, 2019). However, to reach these goals on a local scale, Regional Energy Strategies (RES) are critical and part of the work of the provinces (Regionale-Energiestrategie.nl, 2021). Therefore, within this Regional Integration Project we explore the prospect of local implementation towards sustainability in the Utrechtse Heuvelrug national park, through the use of biomass energy. The Heuvelrug area is situated in the middle of an urban area and has diverse nature, with different types of forests, heathlands, sandy plains and floodplains (Nationaal Park de Utrechtse Heuvelrug, 2021).

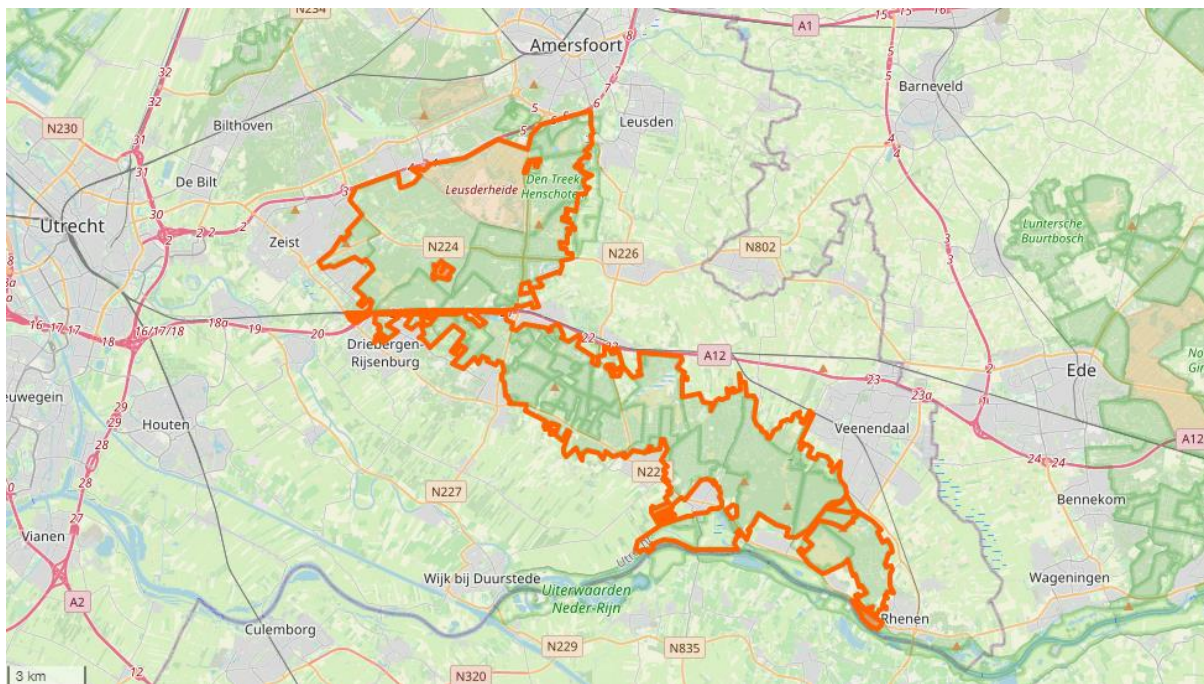


Fig.1. Relation: Nationaal Park De Utrechtse Heuvelrug. The Utrechtse Heuvelrug is shown to be outlined in orange.
Source: Open Street Maps

While biomass may be considered as a renewable energy resource to some, there are conflicting opinions on its level of sustainability as it is often associated with deforestation, pollution from agriculture, and biodiversity loss (Smedema, 2019). Possible areas for biomass extraction are also limited by factors such as logistical and financial barriers and legal frames (Pasma, 2021). Appropriate technologies are required to ensure the reduction of emissions and forest management needs to consider the societal value of the forest to citizens but also environmental aspects. This includes the assessment of biodiversity and the stability of the ecosystem. Another critical aspect is the understanding of the effect of changing climatic conditions on the forests (Nabuurs, 2020). Moreover, to ensure sustainability, relevant stakeholders from different sectors need to be involved (Price, 2007),

including governmental organizations, private owners, civil society, land owners, nature organisations and energy producers (Nationaal Park Heuvelrug, 2018).

The aim of our research is to assess the potential of biomass extraction in the Utrechtse Heuvelrug for sustainable energy production. This leads to the following research question: **“To what extent can the Utrechtse Heuvelrug be used as a sustainable source of biomass for energy production, considering the technological, socio-economic and environmental circumstances?”**

For further clarification and structure, multiple sub-questions were composed. The sub-questions are as follows:

1. What are the existing technologies within a suitable proximity around the Utrechtse Heuvelrug for converting biomass into an energy resource? Which technology can be best utilized in Utrechtse Heuvelrug?
2. How can forest biomass be utilized without decreasing the forest’s resilience against climate change?
3. What is the potential for biomass extraction from the Utrechtse Heuvelrug to supply sustainable energy?
4. How can the utilization of the Utrechtse Heuvelrug as a biomass energy source fulfill both the social and economic needs of Utrecht citizens?

The first two questions allow us to develop a greater insight into the foundations of biomass production and forest management in the Utrechtse Heuvelrug. The last two questions focus on the social, economic and ecological effects of biomass energy production.

2 Literature Review

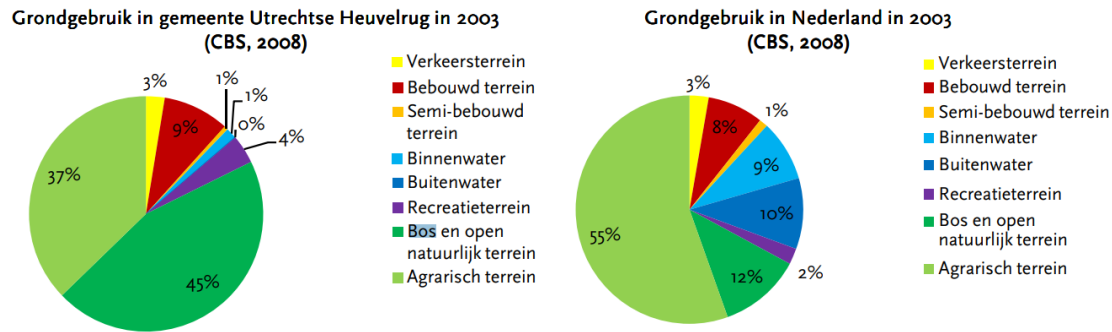
Bioenergy production since the 1990s has dramatically increased as government policies have focused more on the implementation of sustainable energy production. It has also played a key role in the production of renewable energy today as the largest form of renewable energy used (Smedema, 2019). Furthermore, though bioenergy has many sources, this research report will focus on biomass production from forests. However, with the use of forest biomass come concerns of negative impacts. This is where the concept of sustainable forest management comes into play.

Sustainable forest management is threefold. Ecological, socio-economic and technological factors should be taken into account. Additionally, it needs to include hidden stakeholders, e.g. Future generations and communities elsewhere, and aim for socially responsible solutions (Price, 2007). Biomass extraction can have negative impacts on the ecology, which is why forest management needs to carefully outweigh its economic and environmental benefits (Price, 2007). While the paper by Prince gives a good overview of management strategies and its role, it does not provide a clear solution on the most suitable sustainable management method, taking into account hidden stakeholders. In this research paper we will try to find the right management method for the Utrechtse Heuvelrug.

From an ecological perspective forests are complex ecosystems in constant interaction to their environment. Climate change and human activities pose great risks for the health of forests. While rainfall has gotten more unreliable in both duration and extent, rainfall in the Netherlands has increased by 20% since 1950 (Nawazia, 2018). Heavy rainfall can lead to the forest's inability to absorb nutrients being flushed out (Verkaik, 2009). Climate change also exacerbates the problem of invasive species and pest outbreaks (Hellmann et al., 2009). Unfortunately, there are no public evaluations of the Utrechtse Heuvelrug health or its climate impacts. Such information must be obtained within interviews with the stakeholders or within the fieldwork.

Furthermore, the Utrechtse Heuvelrug has nearly 4 times as much natural area ("Bos en natuurlijk terrein") than the average area in The Netherlands (see Fig 2). However, there is no data to estimate the economic efficiency of biomass extraction for the Utrechtse Heuvelrug. A study from Daigneault et al. (2012) has shown that if economic conditions are appropriate, the use of biomass for energy production can lead to reduced total carbon emissions. They used the "consumers surplus minus the costs of holding timberland and managing it" to express the net welfare of extracting biomass for energy. This framework is transferable to our case study since the crucial economic conditions are sufficiently similar. After all, energy out of biomass production belongs to the most effective strategies for decreasing greenhouse gas emissions and global warming (Antara, et al., 2021). An investment into biomass

therefore shows great prospects.



Cirkeldiagrammen geven de karakteristiek van onze gemeente weer

Fig 2: Difference in land usage (“Grondgebruik”) of the Utrechtse Heuvelrug to the average land use of the Netherlands in 2008. Source: Gemeente Utrechtse Heuvelrug. (2010).

Once again there is not sufficient data on the potential of biomass extraction in the Utrechtse Heuvelrug. However, several different indicators can serve the estimation of the potential biomass extraction. The “crown area index (CAI) of stands” indicates the biomass production by canopy area per unit ground area (Coomes, D. et al., 2021). Programs such as QGIS and additional satellite pictures are suitable (Brown, 1997). The ‘harvest method’ (Monk et al. 1970) estimates biomass production by first sampling litter layers which are then harvested, dried and weighed. However, an accurate estimation of the biomass is difficult to achieve, time consuming and still liable to error. Therefore we seek to receive helpful insights from the main stakeholders to determine how we will continue.

Finally, research was done to investigate the available technologies for converting biomass into energy. There are currently multiple small biomass plants near the Utrechtse Heuvelrug, as is depicted in Fig 3. The Eneco Biowarmte-installatie Lage Weide, though not displayed on the map, is a large player in the biomass energy supply (Eneco.nl, 2021).

To conclude, our literature review served as an important baseline for our research, giving a comprehensive overview of relevant environmental, social, logistical, technological and economic factors. However, as there is little data and research done on the Utrechtse Heuvelrug, stakeholders are most important to acquire more information.

Fig.3. Map showing biomass plants surrounding the Utrechtse Heuvelrug. Source: Algemene Vereniging Inlands Hout



3. Methods

The final methodology differed from what was described in the research proposal due to early indications that some intended research steps are not possible and that there is no potential for sustainable biomass extraction. The soil is too bare. Therefore, all organic matter should remain in the area (Van Dun, 2021). However, this would be a very short answer so we decided to discover the broader context of Utrechtse Heuvelrug's forest management and the factors that come into play when deciding on biomass extraction. This might be a valuable addition to the discussion regarding the topic and helpful for related research, concerning this area and other areas.

As the Utrechtse Heuvelrug is classified as unsuitable for biomass extraction, the determination of suitable energy plants, technologies and testing areas turned needless. However, to answer our research question comprehensively information about energy plants, technologies and the division of management and land use matters. When stakeholders could not advise us on the exact calculations of biomass productions nor provide any crucial data, we used the qualitative data acquired in the interviews and satellite pictures to draw a rough picture of the biomass production.

The methodology of this report is divided into three sections (also see Fig. 4). Section one will address the approach taken towards the literature review, the composing of sub questions and the choice of organizations for interview. Section two introduces the semi-structured interviews. Lastly, section three will discuss how the data collected in the interviews were processed through the use of coding and GIS.3.1: Literature Review, Sub questions and contacting Organizations

First, a detailed literature review was conducted to understand environmental, social, technological and economic aspects of biomass energy in general. Subsequently, the collected information was assessed and classified in order to compose the sub-questions (see Introduction) that aim to determine the specific aspects playing into account in the Utrechtse Heuvelrug.

Based on these sub questions five organizations were contacted through email and phone call. Each organization was selected as we expected them to have relevant data on the topic of biomass that would assist us in answering our research question and sub questions.

The five organizations are as follows:

- o Landschap Erfgoed Utrecht: This volunteer organization (Pasman, 2021) is involved in improving the quality of landscapes and the preservation of biodiversity in the Netherlands. They should be able to inform us on the effects of biomass extraction on the landscape and ecosystems of the Heuvelrug.
- o De Bomenstichting: This volunteer organization protects and promotes the care of trees through offering advice and information. (Lommerse, 2021). They were contacted to get information on how the health of the forests in the national park would be affected and whether they could produce enough biomass for extraction.

o Groenrecycling Utrecht B.V.: This business processes green waste to form biomass which can be utilized for several products. (Agterberg, 2021) In addition to offering us more information on biomass and technologies, they would be able to provide us with information on the different possible uses of biomass other than energy.

o Staatsbosbeheer: This is a Dutch governmental organisation that is responsible for the management of the Dutch forests. They are a landowner in the Utrechtse Heuvelrug and an important manager (Van Dun, 2021). We expect them to have the most information on the area and they will be able to tell us about the potential of biomass production in the area.

o Natuurmonumenten: This organisation manages and owns land in the Utrechtse Heuvelrug. (Natuurmonumenten, 2021) This organisation has members and works with volunteers. We contacted the organisation for an interview as they are landowner and manager in the Utrechtse Heuvelrug. They would be able to offer information on the forests' prospect as a source of biomass extraction.

3.2: Semi- Structured Interviews

We conducted semi-structured interviews to encourage in depth explanations, allow for follow up questions and collect vast amounts of information while ensuring specific questions are answered. In the designed interview guide the emphasis was kept on the perspective of the interviewee and questions were based on their area of expertise of each organization. For example, questions on forest and tree health were mainly posed to De Bomenstichting whereas questions pertaining to the potential of biomass extraction in the Heuvelrug were posed to Staatsbosbeheer and Natuurmonumenten. Other questions were asked to all stakeholders to get pictures of the same concepts out of different perspectives.

Each interview had a leading and co-interviewer to ensure order in the way in which the questions and follow up questions were asked. The choice of the interviewer depended on the preferred language (Dutch or English) the interviewee spoke. Due to corona restrictions, four of the five interviews were conducted online, but all were recorded with the permission of the interviewee. After each interview, the interview was transcribed.

The persons interviewed from each organization can be found in the table below.

Table1. List of interviewees from each organization.

Organization	Interviewee	Role in organisation	When/Where
Landschap Erfgoed Utrecht	Hein Pasman	Member of the management teams	Online via Teams 2-6-2021
De Bomenstichting	Peter Lommerse	Board member	Online via Teams 10-6-2021

Groenrecycling Utrecht B.V.	Matthijs Agterberg	Manager	On site 2-6-2021
Staatsbosbeheer	Marcel van Dun	Spokesperson	Online via Teams 10-6-2021
Natuurmonumenten	Harald van den Akker	Product Manager Wood & Biomass	Online via Teams 14-6-2021

3.3: Data Processing

The data processing was done in two parts: Coding and GIS analysis.

Part 1: Coding

1. After all interviews were transcribed, each was reviewed, notes taken and discussions held to adapt questions for further interviews and familiarize the received information.
2. A table with six columns was made: one with the key words that came back in different interviews, and then a column for each interviewee. For every keyword, we inserted quotes from the interviews. This increased the efficiency of analyzing the data as all information was summarized in one table and allowed for new insights. (see Annex)

Part 2: GIS Analysis

After processing the data collected, there were some important insights gained that we decided to explore through using GIS. One important insight was that the Heuvelrug was unsuitable for biomass extraction as the soils lack nutrients and are mostly sand.

- Therefore, using QGIS and the raster tool, a map of the soil types in the Netherlands was overlaid on a map of the Netherlands. The Heuvelrug was then outlined and the soil type was explored.
- The area of Flevoland was also outlined to explore its soil type, as it is an area where biomass extraction is already being done. We will then be able to see if there are significant differences in the soil type between the Heuvelrug and Flevoland.
- QGIS is used to explore the vegetation indicated in an infrared picture to compare vegetation density in the Utrechtse Heuvelrug and its surrounding.

Through the literature review, the interviews and maps the discussion and conclusions were formed.

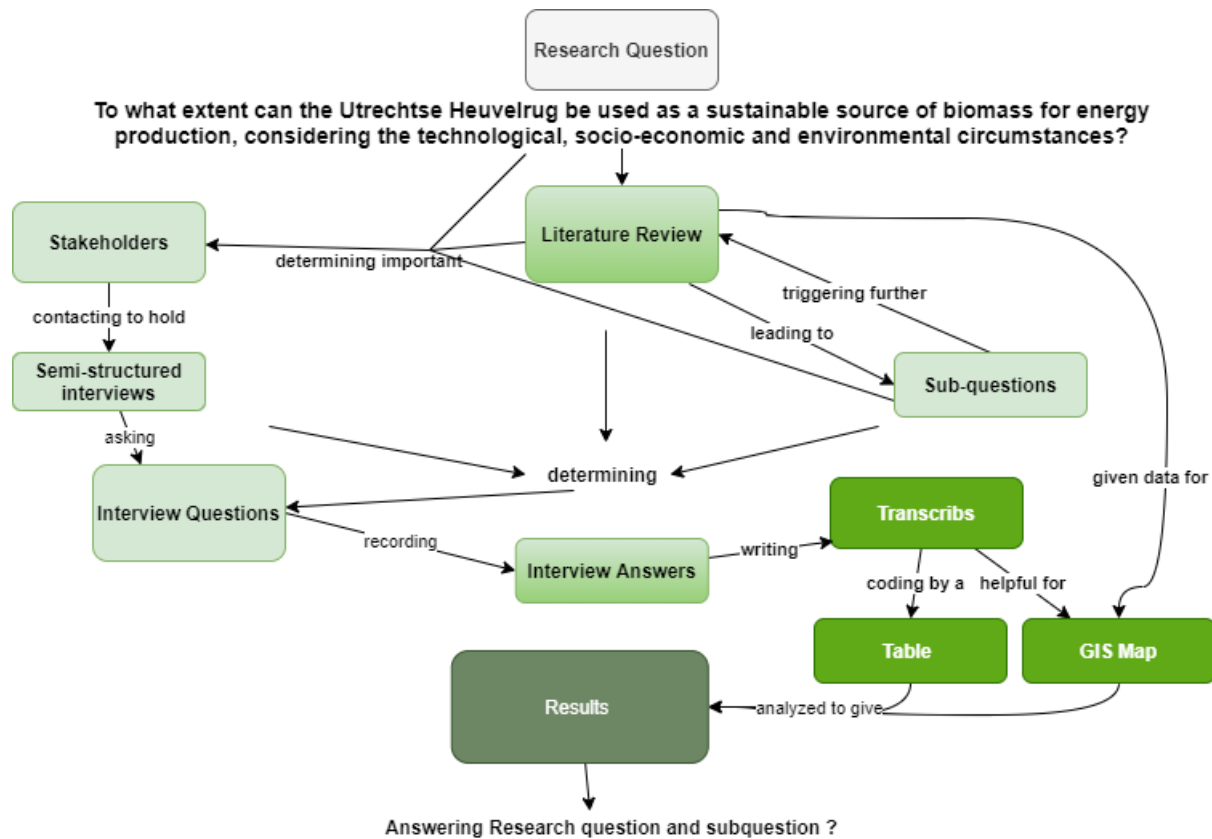


Fig. 4: Concept map of the methods used to conduct results. Developed with app-diagrams.net

4. Results

The above described methods used to conduct and process the data allowed us to find answers to our research questions. In the following, this data is presented and its meaning explained.

4.1. Status quo: No biomass extraction

There is currently no biomass extraction in the Utrechtse Heuvelrug for energy production and no potential for it (Van Dun, 2021), as also confirmed by other interviews (see Annex 2). Natuurmonumenten, however, extracts biomass from grasslands and estates surrounding the Heuvelrug, as the soil are suitable in those areas (Van den Akker, 2021).

4.2. Reasons for no biomass extraction



Fig 5: Map of the soil types within Utrechtse Heuvelrug and its surrounding using QGIS.
Source of Soil Type Map: Wageningen UR - Alterra. (2006)

In richer soil type areas like Flevoland, the Staatsbosbeheer collects the residue wood that is generated from managing the forest for biomass energy. In the Utrechtse Heuvelrug, however, all the tree litter is left on the forest ground. As previously mentioned, this is necessary as the soil in the Heuvelrug is too bare to remove biomass and therefore remove nutrients with it; *“We never harvest biomass there (...) to benefit the soil.”* (Van Dun, 2021).

The type of soil in the Utrechtse Heuvelrug is mainly sandy soil (Wageningen UR, 2006; Van Dun, 2021). Geographical data were used in QGIS to depict the soil types in the area and confirm this (Fig 4). Sandy soils are weakly developed and have a low capacity to hold water (Šimanský et al, 2019). It is generally low in nutrients and other organic matter, making it infertile (Michéli et al., 2019). Soil organic matter, which consists of plant and animal debris, increases the fertility of sandy soils (Šimanský et al, 2019). This is considered in the approach taken by the stakeholders (Van Dun, 2021). If all the tree litter is removed, the soil becomes poorer. This has large effects on biodiversity (Van den Akker, 2021).

4.3. Alternative biomass extraction

An alternative to biomass collection from the forest is to utilize residual wood from urban areas and provide fuel for small scale biomass plants (Pasman, 2021; Van den Akker, 2021). This is promoted in a report from Platform Bio-energie (2017). Other alternative areas for biomass extraction are

agricultural areas and river banks, surrounding the Heuvelrug forest (Pasman, 2021). Here, the soil is not too bare for wood collection. Fig. 5 shows light loam and heavy loam along the river banks.

4.4. Logistics

In previous projects at the Utrechtse Heuvelrug, the distribution of the extracted biomass has been the biggest challenge (Pasman, 2021) due to difficult accessibility and transport of the biomass. Extractors of biomass must take heed of the damages that can be done to the soil and vegetation with large machinery (Pasman, 2021). Horses have been mentioned by Pasman to be used for transport within vulnerable areas. Places to store the biomass in between are also required (Pasman, 2021, (Van den Akker, 2021)). Moreover, the economic and ecological effectiveness needs to be estimated - collecting too little yields of biomass is a waste of resources as there are significant costs involved in the transportation of biomass (Zhang et al., 2011). This relates back to the Heuvelrug, as in most municipalities in the Netherlands including the Heuvelrug, there are not enough trees for biomass extraction (Lommerse, 2021). Lastly, the amount for emissions released during transport is equally important to ensure the sustainability of the fuel (Pasman, 2021).

4.5. Importance of social-economic factors

The area is owned and managed by several different stakeholders, such as organizations but also private owners. In general, this seems to work well (Lommerse, 2021). The area division is depicted in a map (Fig 6) showing the largest areas owned by the Staatsbosbeheer and Utrechtse Landschap.

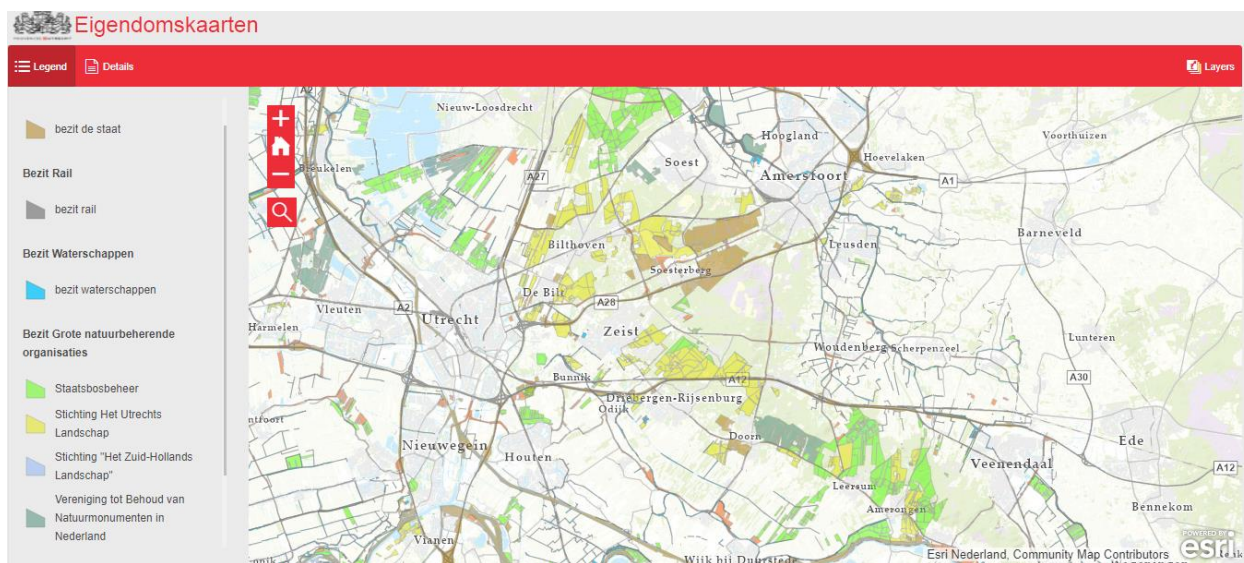


Fig.6: Division of the Utrechtse Heuvelrug by owners. (Provincie Utrecht, 2021) The green areas are owned by the Staatsbosbeheer, the yellow areas by Utrecht Landschap

As the topic description (Daniil Scheifes, 2021) indicated, the area is also divided in different management strategies by foresters such as

- Forest reserves: no management, nature is left on its own.
- Multifunctional forests: serve for several ecosystem services.
- Nature forests: conventional forestry management

The orientation of the management is amongst other things influenced by the regional energy strategies (RES). This is part of the work of the provinces, requiring local solutions for more sustainable energy (Van Dun, 2021). He describes this process as a “political and difficult topic” even though the management of the Landschap Erfgoed Utrecht prioritizes landscape and biodiversity equally to cultural and historical heritage preservation before biomass extraction (Pasman, 2021). Staatsbosbeheer also prioritizes the maintenance of high natural standards in this natural park, supplying “lots of recreation” (Van Dun, 2021). In general, there is an increasing value put on trees and nature (Lommerse, 2021).

Pasman tells us that the financial feasibility of biomass extraction from estates and agricultural areas around the Heuvelrug is highly dependent on the willingness of municipalities to invest in such projects. This money is needed, e.g. to purchase certain machines to make biomass extraction logistically feasible in wetter areas.

Other economic processes, such as the current high wood prices can impact the use of biomass. When land managers and estates extract wood, it's then more attractive to sell it to wood factories. “There is more to be gained financially than from biomass energy” (Pasman, 2021).

Behaviour of individuals, such as farmers and residents, can also affect biomass extraction. In a pilot project, some farmers put all sorts of other wood to the collecting sports for biomass energy, so that the wood could not be classified as clean anymore (Pasman, 2021).

Legal frameworks also need to be suitable since biomass plants might need certifications of the biomass to use it. A so called “NTA 8080” certification does not allow the Groenrecycling Utrecht bv to use biomass other than from residuals (Groenrecycling Utrecht bv, 2021).

4.6 Seen effects of climate change

Climate change poses a great threat for the health of forests, which is a crucial factor for the extraction of biomass. Harald van den Akker from Natuurmonumenten summarized the situation like this:

“Climate change has far-reaching consequences. (...) The Dutch forest has a permanent flu. If you have the flu you are vulnerable and if you get anything on top of it you simply die. This is what Dutch nature looks like.” (Van den Akker, 2021)

Possible problems are “aggravate erosion, decline in organic matter, salinization, soil biodiversity loss, landslides, desertification and flooding” (European Commission, 2020). Negative impacts on biodiversity are manifesting already. Higher temperatures will lead to warmer winters and thereby, less decaying of damaging insects by cold and allowing invasion of southern species (Verkaik, 2009). Increasing draughts have a “negative impact on the growth of a large proportion of our forest” (Verkaik, 2009). In the interviews four stakeholders (Natuurmonumenten, Staatsbosbeheer, De Bomenstichting and Stichting Utrechts Landschap) mentioned droughts and higher temperatures as effects of climate change they observed in the Utrechtse Heuvelrug forest. Higher temperatures in spring and autumn make the resting season of trees shorter (Pasman, 2021). Rainfall is more irregular now (Lommerse, 2021), often it rains a lot after a long dry period. This results in a lower water level, threatening the health of trees. Higher nitrogen deposition is another problem (Lommerse, 2021). The

representative from foundation Natuurmonumenten also notice that indigenous Dutch trees are vulnerable at the moment because of climate change. The Staatsbosbeheer, on the other side, is planning to detect whether native trees have an advantage to non-indigenous trees because they are more adapted to the heat (Van Dun, 2021). Indigenous tree species play an important role in the ecosystem, so their vulnerability endangers the ecosystem (Van den Akker, 2021)

4.7. Methods of biomass extraction

There are multiple different approaches for generating biomass that might be suitable for energy. In general, biomass can be collected from cutting down trees, collecting tree litter or from the management of public gardens and estates in municipalities. However, cutting down and burning trees for energy is often perceived as 'unsustainable' (Smedema, 2019). But there are several situations where cutting of trees is necessary. This can be the prevention of diseases spreading or for biodiversity reasons such as the "thinning" of densely vegetated areas to ensure other organisms get enough sunlight and nutrition to flourish (Van Dun, 2021). To preserve the landscape, cutting sometimes occurs in the heathland fields to prevent trees from slowly taking over the field, converting it into a forest (Van Dun, 2021). In the process of cutting trees, tree litter is produced. This includes the unusable parts of the tree, the branches and the tops, as well as the parts of the tree that fall on the ground (Van Dun, 2021). While the wooden logs are rather sold to the wood industry the leftovers cannot be sold as a better product for biomass energy production (Van Dun, 2021).

5. Discussion

After having collected the results of the literature and the interviews, the broader meaning of the acquired information is discussed and linked to our research questions. In the following, answers to our research questions are introduced, while strengths and limitations are pointed out. Even when it quickly turned out that there is no biomass extraction in the Utrechtse Heuvelrug for energy production, we decided to still further discuss the prepared sub research questions since the according answers give insights in the circumstances on hand, which might be helpful for the exploration of the potential of biomass extraction in other areas and case studies.

5.1: What are the existing technologies within a suitable proximity around the Utrechtse Heuvelrug for converting biomass into an energy resource? Which technology can be best utilized in Utrechtse Heuvelrug?

We have looked at several technologies around the Utrechtse Heuvelrug that exist for converting biomass into an energy resource. A large player in this area is the BioWarmte Installatie Lage Weide. This is a large biomass plant owned by Eneco. In this installation, biomass is burnt to produce heat. This heat is then used to warm up water to about 170 Celsius (Eneco, 2020). The plant is connected to the waternet and the warmed water is used by this waternet. About 25% of the demand for warm water in Utrecht can be supplied by this installation (Eneco, 2020).

The Groenrecycling Utrecht retrieves biomass and converts it into compost. The incoming biomass is sorted and shredded. Then it gets thrown onto a big pile where it lays for several weeks. During this time the biomass is slowly decomposing into compost. When the compost is ready it is mixed with other materials like sand and manure, to turn it into end products which can be sold (Agterberg, 2021). This is a very interesting use case for biomass. In this process the burning of biomass is avoided, which is a positive since it is a controversial aspect of biomass energy production. Furthermore, most kinds of biomass are suitable for this process compared to biomass plants which only accept high-grade biomass.



Fig. 7: Infrared picture, conducted from geodata.nationaalregister.nl in 2021.

Even when the Utrechtse Heuvelrug might not be suitable for biomass extraction, other areas in proximity might be suitable. Fig. 7 shows a higher vegetation density (darker green) in other areas beside the Utrechtse Heuvelrug and the Flevoland.

5.2: How can forest biomass be utilized without decreasing the forest's resilience against climate change?

The literature review indicated an opportunity of forest health or more specifically biodiversity to improve biomass production. To improve biomass production it is therefore crucial to stabilise the forest against climate change and keep it healthy.

An article by Bradley J. Cardinale suggests exactly that. It portrays that “mixtures of species produce an average of 1.7 times more biomass than species monocultures and are more productive than the average monoculture in 79% of all experiments” (Cardinale, 2007). This can be explained as a more biodiverse environment can adapt more quickly to environmental changes. As biodiversity is a crucial part of forest's health, it is important to avoid any negative human impacts on the forest. “Harvesting for any products should be done with forest health in mind” (Forestry.nl, 2019) If biomass extraction is not managed well it can negatively impact the health of the forest “sustainable harvesting practices protect the environment by conserving soil, controlling stream sedimentation, protecting residual trees from damage, and promoting desired regeneration.” (Finley, 2006).

This portrays that biomass production can have negative effects on the ecosystem by damaging it and therefore reducing the forest health. This is exactly the reason why biomass extraction in the Utrechtse Heuvelrug is not possible, it would deplete the forest and reduce its health which would lead to a lower resilience against climate change. This view is as well shared with the Staatsbosbeheer as mentioned. However, more research needs to be done into which tree species are the most resilient against climate change (Van Dun, 2021). Such trees could then be increasingly planted. Since draughts and lower water level are one problematic aspect of climate change for the forest (Lommerse, 2021), forest and water management should work closely together to dampen harmful effects.

5.3: What is the potential for biomass extraction from the Utrechtse Heuvelrug to supply sustainable energy?

From an emissions perspective, biomass is a sustainable alternative to fossil fuels. When biomass from close by areas is used, the CO₂ reduction of using biomass energy over fossil fuels is above 70% (Platform bio-energie, 2017). Since the Utrechtse Heuvelrug is situated in an urban area, it seems to have potential for producing biomass for the nearby urban areas.

However, based on the information that was obtained from the interviews we concluded that there was no potential for biomass extraction in the Utrechtse Heuvelrug. As presented in the result section, there are multiple reasons for this, the main reason being the poor sandy soils and logistical problems (Van Dun, 2021; Pasman, 2021). This argument is backed up by researchers, who also say that sandy soils are nutrient poor soils, and that soil organic matter helps to fertilize the soil (Šimanský et al, 2019; Michéli et al., 2019). This implies that there is no possibility of extracting tree litter from the Heuvelrug without damaging the ecosystem.

We planned on using natural science methods to estimate the potential of biomass energy for the Utrechtse Heuvelrug forest, however there was no need to do this because of external factors that make the extraction of biomass from the Heuvelrug undesirable. First of all, extracting biomass is undesirable for the ecosystem (Van Dun, 2021). On the other hand distributional and financial restrictions complicate the extraction of biomass in areas where the soil is richer. (Pasma, 2021; Van den Akker, 2021) In our research we have only looked at the Utrechtse Heuvelrug area. There might be potential for biomass production in municipalities and agricultural areas around the Utrechtse Heuvelrug. Both the representative from Natuurmonumenten and Stichting Utrechts Landschap mentioned the possibility of small scale biomass plants that warm single buildings and source the wood they use locally. It would be interesting to research the potential of these types of small scale biomass plants and their role in sustainable energy production. When small biomass plants use local residual flows of wood and use this to heat or electricity to heat for example a residential area or a swimming pool, biomass can visibly fulfill the needs of citizens.

We can conclude that our findings do implicate that biomass production is simply not feasible in the Utrechtse Heuvelrug and that the reasons to not extract biomass are based on scientific knowledge, however, there might be alternatives to extract biomass from areas surrounding the Heuvelrug.

5.4: How can the utilization of the Utrechtse Heuvelrug as a biomass fuel source fulfill both the social and economic needs of Utrecht citizens?

The literature review and the interviews reflected that biomass extraction in the Utrechtse Heuvelrug for energy production is not feasible since it stands in a trade-off to social and economic aspects. The interviews with the different stakeholders pointed out the importance put on the ecosystem service of recreation from forest areas. This is the priority in the management of the Staatsbosbeier and the value put on nature is also increasing by visitors and citizens. However, the needs of future generations need to be taken into account too, and therefore it might be arguable to reduce recreation opportunities in order to supply more sustainable energy.

Out of an economical perspective, the Utrechtse Heuvelrug can serve the best when financial supply is ensured. Management takes money. Volunteering is needed, but political institutions need to supply enough money too. Economic principles need to be adapted so that it is economically valuable to invest in biomass production.

As mentioned in section 3, when small biomass plants use local residual flows of wood and use this to heat or electricity to heat for example a residential area or a swimming pool, biomass can visibly fulfill the needs of citizens. The Dutch government promotes these small initiatives, where the wood is locally sourced and is used again locally too. An additional advantage of small scale biomass plants is that the transport costs and emissions for transporting the wood are low (Pasma, 2021). When biomass from close by areas is used, the CO₂ reduction of using biomass energy over fossil fuels is above 70%. (Platform bioenergie, 2017) By using only residual flows of wood from nature management around the forest, sustainability is ensured (Lommerse, 2021). Hein Pasman from Landschap Erfgoed Utrecht explained in his interview that collecting biomass from areas surrounding the Heuvelrug forest is possible, mostly from agricultural areas and from the river banks. The soil there is not too bare and wood can be collected.

5.5 Main findings: Strengths and limitations

Overall, this paper has been the first to collect statements of different stakeholders involved in the Utrechtse Heuvelrug about such specific questions concerning biomass extraction for energy

production. Thereby it adds to the process of collaboration by communication. The area is perceived as a valuable recreation area. Nature, including its ecosystem services but also its perceived intrinsic value, is aimed to be preserved. Therefore management needs to be sustainable to supply these services in the future. Health of the forest, biodiversity and landscape fostering is a priority. Therefore, when considering biomass extraction, the conditions of the forest need to be closely taken into account. The bare soil does not allow extraction of biomass, but the logistic challenges linked are equally difficult. The forest should not be negatively impacted. Climate change exacerbates the problem of the health of the forest. There needs to be a discussion of the balance between the needs of today's generation and future generations, whether recreation is more important than sustainable energy. However, for that exact quantitative data on these topics is missing, which could open new insights and trigger different management strategies. A limitation of this research was the small scope of research. Further research could be done into using biomass from other areas around the Heuvelrug.

6. Conclusion

Humanity is looking for sustainable energy sources to secure the future. Biomass energy production is one of the potential solutions to replace non-renewable energy sources. Since the Netherlands has forests, the possibility of using biomass can be explored. We have done this for a specific area, the "Utrechtse Heuvelrug". In our research we elaborated on the possibility to utilise the Utrechtse Heuvelrug for biomass production. To determine the potential, we conducted qualitative research as well as assessing quantitative data retrieved from previous literature.

To begin with there is no biomass extraction in the Utrechtse Heuvelrug. This has several reasons which became apparent in our research. Priority in the management is to sustain the biodiversity and landscape to receive ecosystem services (mainly recreation) by fostering the health of the forest. For the forest, extracting biomass means an extraction of nutrients and disturbance by logistical processes. This can be tolerated in some areas but it turns out that the Utrechtse Heuvelrug is ecologically not suitable to ensure sustainable extraction. The soil contains little nutrients and extracting biomass, therefore removing nutrients from the nutrient cycle, would have negative effects on the forest health (Van Dun, 2021; Lommerse, 2021). Stakeholders therefore do not support any kind of biomass extraction in the Utrechtse Heuvelrug. Another important factor to consider when evaluating the potential is to detect other environmentally influencing effects like climate change. Climate change has a negative impact on the overall well-being of the forest. As biomass extraction itself already would have an adverse influence on the Utrechtse Heuvelrug, combining this with the multiple effects of climate change would be devastating. In addition to that the forest, even if biomass could be extracted, would not allow easy collection of biomass there due to the local structure. It would require costly and intensive methods to collect the biomass which is imbalanced to the potential profit, both economically and ecologically. Socio-economic structures can also prevent the potential use of biomass and need to be taken into account in the planning.

As stated in the beginning according to the United Nations sustainable energy production is inevitable when discussing future human living. The Utrechtse Heuvelrug is unfortunately not able to gain from producing biomass for energy production itself due to the above mentioned environmental and socio-economic reasons. We advise the Utrechtse Heuvelrug therefore to look into other possible sources of sustainable energy like extension of photovoltaic, or wind energy. These might be less harmful for the ecosystem and the impact on the landscape is to neglect considering the urgent need for sustainable energy. Another possibility could be partnering with another municipality which could supply the Utrechtse Heuvelrug with biomass. In general, it needs to be invested in quantification of cost and profit, in social, economical and ecological aspects in order to optimize management.

We advise future research when assessing potential biomass extraction to classify the areas into possibilities before doing extensive research. This would aid avoiding focusing on clearly not suitable areas and allow for scientifically significant and beneficial results.

7. Relevance and Integration

The research question aims to assess tree litter extraction in the Utrechtse Heuvelrug with strong regards to a sustainable method and implementation. We anticipate our results to indicate the feasibility and execution of this potential biomass production. The feasibility will be assessed by showing how local, technological, and climatic conditions would influence the biomass production.

The local aspect strongly correlates with the topic of “woody plant diversity” (group 1A) as this indicates the available types of biomass which are crucial for a correct estimation of the potential total energy which can be extracted. Different species of trees grow at different rates and exactly knowing which species are prevailing, how fast they regrow is vital for our assessment (Pretzsch, 2009). But that is not the only role the “woody plant diversity” plays in our research, combined with the topic of “bird and mammal diversity” (group 1B) we can assess the overall biodiversity of the Utrechtse Heuvelrug. This is essential for determining the suitability of the forest itself, as “there is increasing evidence that biodiversity contributes to forest ecosystem functioning and the provision of ecosystem services” (Eckehard G. Brockerhoff, 2017). Wood supply is a “provisioning ecosystem service” (Greenfacts, 2021) making ecosystem biodiversity a key factor in forest assessment. Biodiversity was something taken for granted, so strongly that until the 1980s there was not even a term for it, not to mention any serious research into the topic (José L., 2013). The more extensive the research got the more apparent became the concern that the system of biodiversity was fragile, and human activity was threatening to destroy it. “Invasive alien species” (group 1C) pose a big threat for biodiversity, which in return leads to “annual environmental losses caused by introduced pests in the United States, United Kingdom, Australia, South Africa, India and Brazil”, which “have been calculated at over US\$ 100 billion” (Secretariat of the Convention on Biological Diversity, 2011). There is no direct estimation for the Netherlands nor the Utrechtse Heuvelrug, but the data suggest that potential damages could have a similar economic impact. The economic loss is caused by ecosystem destruction, which also affects forests and could therefore severely impact potential biomass production if invasive species were introduced into the Utrechtse Heuvelrug. This threat needs to be taken into consideration when assessing potential biomass production, as well as the advice to take precautionary actions. Social acceptance and support, like discussed in “Forest perception residents and foresters” (group 1E and group 1F) is a vital aspect to be taken into consideration as well when estimating potential biomass production. The absence of social support for biomass extraction could obstruct the entire undertaking. But it is not only social support which is needed but also social protection from negative impacts of biomass extraction.

This clearly shows that an interdisciplinary approach is necessary to answer our research question, as it is impossible and reprehensible to undertake research without taking all possible interferences and outcomes into consideration.

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9. Annex

In the annex, figures and tables that are not displayed in the report itself can be found. This appendix contains the interview guide, the interview analysis table and GIS images used in the analysis.

Annex 1- Interview guide Utrechtse Heuvelrug stakeholders

Introduction

Introduce yourself as interviewer

First of all, thank you for participating in this interview! This interview will take around 30 minutes. This interview is part of an interview series with stakeholders in the Utrechtse Heuvelrug region for a research project. The goal of this research paper is to add to the discussion of how biomass extraction for energy production in the National park can be implemented in a sustainable way. It is important for us to understand the different viewpoints and knowledge of various stakeholders to get a good view of the situation. Therefore your insights will be really helpful for our research.

Ethics statement

Your privacy will be guaranteed. The recording of this interview will only be used by us and the recording will not be published. Your personal information will not be published unless permission is granted. With your permission we will use the interview answers and your name and function in our report.

To analyze and use the data from this interview, we will transcribe it from the recording and use this to gather information.

Now ask the interviewee for informed consent to record the interview. Ask the interviewee if they still want to participate. If the interviewee does not give consent for recording the interview ask them for consent to take notes during the interview.

Interview 1

Time	9:00- Wednesday
Name of the Stakeholder:	Landschap Erfgoed Utrecht
Role of the Stakeholder (general):	Utrecht Heuvelrug Land Owner
Members leading the interview	Charlotte

General Facts of Landschap Erfgoed Utrecht:

- o Established in 1980
- o Manages agrarian land
- o Goal: Promoting the preservation of the natural and landscape beauty and cultural history in the province of Utrecht. This includes everything that benefits the quality of nature and the landscape in the province of Utrecht.

Questions:

1. Can you describe the role of your organization in the Utrechtse Heuvelrug?
2. Can you tell us more about the different managed areas in the Utrechtse Heuvelrug?
(Multifunctional productive forest zones, nature forest, forest reserves.)
What characteristics/causes make them managed differently?
3. How are these characteristics linked to biomass production?
4. Is there a map or public data available indicating the different managed areas? Where can we access it?
5. Your organization states that the promotion of the preservation of nature is one of its main goals. Biomass based energy can be seen as a means to preserve nature as it can be viewed as a renewable energy source. What is your opinion on energy production out of biomass from the Utrechtse Heuvelrug?
6. All Dutch municipalities are making a plan for the energy transition from gas. Should they include biomass in this plan? Why?
In your professional opinion, do you believe that the Utrecht Heuvelrug can be utilized as a source of tree litter for biomass based energy production?
7. Is there specific data about the biomass production per area in the Utrechtse Heuvelrug? How has this data been conducted? How can we get this data?
8. How do you believe this biomass extraction would affect the forest? What should be taken into account when extracting biomass?
9. If there is currently no extraction of biomass for energy production, what are the main reasons for it? Is there something done to change it towards biomass extraction in the future?
10. Which technologies do you consider the most appropriate for energy production from biomass for the Utrechtse Heuvelrug? Why?
11. What is your opinion about the link between energy production out of biomass from the Utrechtse Heuvelrug and sustainability
 - a) Out of a local social perspective?
 - b) Out of a local economic perspective?
 - c) Out of an ecological perspective?

12. Your organization has been in place since 1927, and we are all aware of the phenomenon of climate change. Have you noticed any effects in the forest due to climate change? If not, what other changes have you seen in the forest since then? (e.g. Less forestation)
13. Eneco plans to use the biowarmth plant they installed only as a buffer in 2030, do you think this is feasible and necessary?

Interview 2

Time	11:00- Wednesday
Name of the Stakeholder:	Staatsbosbeheer
Role of the Stakeholder (general):	Utrecht Heuvelrug Land Owner
Members leading the interview	Naomi

General Facts of Staatsbosbeheer:

- o Manages 273,000 hectares
- o Together with companies, governments and research institutes, we work on innovative applications of raw materials from nature and on the development and application of sustainable energy.

Questions

1. Can you briefly explain the role of your organization in the Utrechtse Heuvelrug?
2. Can you briefly explain your function within the Staatsbosbeheer organization?
3. Your organization has made their desire to protect nature known. Biomass production can be seen as a means to preserve nature as it can be viewed as a renewable energy source. What is your opinion on energy production out of biomass from the Utrechtse Heuvelrug?
4. All Dutch municipalities are making a plan for the energy transition from gas. Should they include biomass in this plan? Why?
5. In your professional opinion, do you believe that the Utrecht Heuvelrug can be utilized as a source of tree litter for biomass production? Why or why not?
6. What challenges do you see concerning biomass production, if there are any?
7. What advantages do you see concerning biomass production, if there are any?
8. Are there any maps you can provide showing the different soil types of the Heuvelrug?
9. What are the main species of tree grown in the Heuvelrug?
10. If tree litter was to be collected from the Heuvelrug, how would this be done? What do you take into account when considering a place for biomass collection?
11. Is there biomass production going on that uses tree litter collection in the Utrechtse Heuvelrug, how and where?
12. Are there any economic or social opportunities for the Heuvelrug if it is utilized as a source of biomass production?
13. How do you believe this biomass production would affect the forest? What should be taken into account when biomass is collected from the forest for production?
14. Your organization has been in place since 1888, and we are all aware of the phenomenon of climate change. Have you noticed any effects in the forest due to climate change? If not, what other changes have you seen in the forest since then? (e.g. Less densely forested areas)

15. Together with companies, governments and research institutes, the Staatsbosbeheer works on innovative applications of raw materials from nature and on the development and application of sustainable energy. Can you elaborate more on how the organization does this?
16. Can the Heuvelrug be used as a source of other renewable energy forms?

Interview 3

Time	15:00- Wednesday
Name of the Stakeholder:	Groenrecycling Utrecht B.V.
Role of the Stakeholder (general):	Utrecht Heuvelrug Recycling Company
Members leading the interview	Charlotte, Guus and Lilli

Questions:

1. How is the tree litter collected? How does the litter get here from the place where it is collected?
2. Do you know where the biomass comes from? Do you use tree litter from the Utrechtse Heuvelrug?
3. What kind of tree litter is useful for biomass plants?
4. Where does the biomass go?
5. How sustainable is the process in this plant?
6. In your eyes, are there still problems that should be solved concerning biomass energy production?
7. Do you ever get negative reactions from people about biomass production, since biomass is a contested topic?
8. What stakeholders are important for the collection and production of biomass?
9. Can you briefly explain the role of your organization in the Utrechtse Heuvelrug?
10. Can you briefly explain your function within the Staatsbosbeheer organisation?
11. Your organization has made their desire to protect nature known. Biomass production can be seen as a means to preserve nature as it can be viewed as a renewable energy source. What is your opinion on energy production out of biomass from the Utrechtse Heuvelrug?
12. All Dutch municipalities are making a plan for the energy transition from gas. Should they include biomass in this plan? Why?
13. In your professional opinion, do you believe that the Utrecht Heuvelrug can be utilized as a source of tree litter for biomass production? Why or why not?
14. What challenges do you see concerning biomass production, if there are any?
15. What advantages do you see concerning biomass production, if there are any?
16. Are there any maps you can provide showing the different soil types of the Heuvelrug?
17. What are the main species of tree grown in the Heuvelrug?
18. If tree litter was to be collected from the Heuvelrug, how would this be done? What do you take into account when considering a place for biomass collection?
19. Is there biomass production going on that uses tree litter collection in the Utrechtse Heuvelrug, how and where?

20. Are there any economic or social opportunities for the Heuvelrug if it is utilized as a source of biomass production?
21. How do you believe this biomass production would affect the forest? What should be taken into account when biomass is collected from the forest for production?
22. Your organization has been in place since 1888, and we are all aware of the phenomenon of climate change. Have you noticed any effects in the forest due to climate change? If not, what other changes have you seen in the forest since then? (e.g. Less densely forested areas)
23. Together with companies, governments and research institutes, the Staatsbosbeheer works on innovative applications of raw materials from nature and on the development and application of sustainable energy. Can you elaborate more on how the organization does this?
24. Can the Heuvelrug be used as a source of other renewable energy forms?

Interview 4

Time	11:00- Wednesday
Name of the Stakeholder:	De Bomenstichting
Role of the Stakeholder (general):	Utrecht Heuvelrug Land Owner
Members leading the interview	Charlotte

General Facts of Bomenstichting:

- o promotes care and attention for trees in the city and in the countryside.
- o Founded in 1970

Questions

1. Can you briefly explain what your organization does?
2. Can you briefly explain your function within de Bomenstichting?
3. Your organization has made their desire to protect trees known, and to prevent cutting them down. Biomass production can be seen as a means to preserve nature as it can be viewed as a renewable energy source. What is your opinion on energy production out of biomass, since trees need to be cut down for this?
4. All Dutch municipalities are making a plan for the energy transition from gas. Should they include biomass in this plan? Why?
5. Has your organization been involved in biomass production?
6. Do you know anything about biomass production in the Utrechtse Heuvelrug?
7. What challenges do you see concerning biomass production, if there are any?
8. What advantages do you see concerning biomass production, if there are any?
9. What are the main species of tree grown in the surrounding of the Utrechtse Heuvelrug?
10. If tree litter was to be collected from the Heuvelrug, how would this be done? What should be taken into account when considering a place for biomass collection? What should be taken into account when biomass is collected from the forest for production?
11. Are there any economic or social opportunities for the Heuvelrug if it is utilized as a source of biomass production?
12. How do you believe this biomass production would affect the forest?

13. Your organization has been in place since 1970, and we are all aware of the phenomenon of climate change. Have you noticed any effects in the forest due to climate change? If not, what other changes have you seen in the forest since then? (e.g. Less densely forested areas)
14. Can the Heuvelrug be used as a source of other renewable energy forms?
15. You say on your website that people are connected to trees. Can you elaborate on how you see this? How does this influence how we should treat trees?

Interview 5

Time	10:30- Monday
Name of the Stakeholder:	Natuurmonumenten
Role of the Stakeholder (general):	Utrecht Heuvelrug Land Owner
Members leading the interview	Guus and Charlotte

Questions

1. Can you briefly explain what your organisation does?
2. Can you briefly explain your function within Natuurmonumenten?
3. Has your organisation been involved in biomass production?
4. Your organization has made their desire to protect nature known. Biomass production can be seen as a means to preserve nature as it can be viewed as a renewable energy source. What is your opinion on energy production out of biomass from the Utrechtse Heuvelrug?
5. All Dutch municipalities are making a plan for the energy transition from gas. Should they include biomass in this plan? Why?
6. Do you know anything about biomass production in the Utrechtse Heuvelrug?
7. What challenges do you see concerning biomass production, if there are any?
8. What advantages do you see concerning biomass production, if there are any?
9. What are the main species of tree grown in the surrounding of the Utrechtse Heuvelrug?
10. If tree litter was to be collected from the Heuvelrug, how would this be done? What should be taken into account when considering a place for biomass collection? What should be taken into account when biomass is collected from the forest for production?
11. Are there any economic or social opportunities for the Heuvelrug if it is utilized as a source of biomass production?
12. How do you believe this biomass production would affect the forest?
13. Your organization has been in place since 1970, and we are all aware of the phenomenon of climate change. Have you noticed any effects in the forest due to climate change? If not, what other changes have you seen in the forest since then? (e.g. Less densely forested areas)
14. Can the Heuvelrug be used as a source of other renewable energy forms?
15. You say on your website that people are connected to trees. Can you elaborate on how you see this? How does this influence how we should treat trees?

Annex 2- Interview Analysis Table

Table3. Interview Analysis Table. Table showing the coded and organized data obtained from 5 interviews.

	Marcel van Dun, Staatsbosbeheer, 10-6-2021, online interview	Hein Pasman, Landschap Erfgoed Utrecht, 2-6-2021, online interview	Matthijs Agterberg, Groenrecycling Utrecht bv, 2-6-2021, interview on site	Peter Lommerse, De Bomenstichting, 10-6-2021, online interview	Harald van den Akker, Natuurmonumenten, 14-6-2021, online interview
Current biomass extraction	Normally tree litter is used for this, but not in the Utrechtse Heuvelrug. That is because the soil is too bare. It is sandy soil with little nutrients. <i>"We never harvest biomass (in the Utrechtse Heuvelrug), the tranches stay on the ground to benefit the soil."</i>	Leftover biomass from management of landscape elements around the Heuvelrug	We get no biomass from the Utrechtse Heuvelrug, but mostly from municipalities from park management.		We mostly extract grasses, because they have to be mowed. In the Heuvelrug there is not a lot of grassland, but mostly forest. We don't harvest biomass from the forest, we leave the tree litter we prune in the forest.
Biomass used for energy production Heuvelrug	Not happening.	This is not happening at the moment	A small part of the biomass we get goes to an energy plant, simply because we don't have the capacity to use all the biomass that we receive		Around 600 tonnes a year in my estimation. But this is not from the Heuvelrug itself, but from grasslands around it and estates.

			here. Around 600 tonnes a year of biomass for energy.		
Distribution problems		It is hard to collect biomass without damaging nature			
Bare soil	Sandy soil	Not a problem for agricultural areas and river banks			
Logistics		It is hard to distribute and collect biomass from agricultural areas around the Heuvelrug			Transport of biomass is expensive.
Climate change	Lack of water, drought.	Trees rest later and shorter, there is more drought		Rainfall is irregular and temperatures are higher	The Dutch forests are sick. The trees are very vulnerable. Small things that would not have been a problem in the past kill the trees now because they are vulnerable. Indigenous trees die, although their role in the ecosystem is vital.

Combating climate change	Planting trees that can resist the drought better	I hope that the indigenous trees will be able to recover, they are better for the ecosystem than exotic trees.			
Small scale biomass plants		Little transport, so more sustainable			Very good solution, only sustainable long term way to use biomass energy in my opinion.
Economic aspects	Collecting biomass is expensive	Hard to get finances for biomass projects	Producing biomass for energy yields very little money. It is absolutely not economically feasible to just produce biomass for energy production. We also produce compost, which is where our revenues come from. To make enough, we need to make people pay to bring their biomass here.		Using biomass for energy production is very expensive for us. We rather use our leftover biomass for other purposes, since that is cheaper. <i>"Dumping biomass at a green waste processor costs about 30-40 euros per ton. That's a lot of money, because it also has to be transported. Transport costs about 10 euros per ton. We would rather not spend this money."</i>

Sustainability of biomass energy		Local biomass plants make it a lot more sustainable	In my opinion, burning biomass is a better option than using land for solar or wind farms. But only if the wood is residual wood, not if trees are cut down just for biomass energy.	In our opinion, biomass is sustainable as long as only clean residual wood is used and no trees are cut down for biomass. However, you should also not remove all the debris from forests so you have to be careful with that too.	<i>"Biomass is now seen as a transition fuel. I think that in the long run, biomass will no longer be needed for energy supply. The wood can be better used for such things as furniture making. Burning is one of the worst things you can do with biomass, there are much better options to use it."</i>
Biomass compared to other renewables		Solar and wind-energy are more sustainable and should be the main sources, but biomass should be used too	Biomass will be needed towards the transition away from gas.	Only biomass energy will not be enough in the Netherlands.	
Biodiversity	Using tree litter for biomass makes the forest less vital.	Biomass production is often a trade-off with biodiversity			
Social value				Trees have an important value for people	Making small scale biomass plants has high societal value. It connects people to nature again, since they need the tree litter from management for energy.

