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Using Blockchain Technology to Attract Funding for Nature-based Solutions

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Abstract

Nature-based Solutions (NbS) are natural solutions to societal problems. NbS offer a wide range of benefits to our society, such as climate adaptation and improvements for human health and wellbeing. Nonetheless, the solutions are not yet implemented on a large scale, mainly due to a lack of funding. This paper investigates in what ways blockchain technology can be used to overcome funding barriers that hinder the implementation of Nature-based Solutions. Qualitative research was conducted using a triangulation of data sources for robust and viable results. A framework was developed explaining the two blockchain-based mechanisms that are used to attract funding for NbS. Mechanism 1 uses blockchain to tokenize natural assets to improve their tradability, while mechanism 2 combines multiple technologies to monitor and maintain NbS more efficiently and transparently. The field is still emerging, and there are some limitations, but the outlook of using these mechanisms to increase funding for Nature-based Solutions is promising.

JEL-codes: F64, H41, H54,
Keywords: Nature-based Solutions, Blockchain, Sustainable Finance, Green Infrastructure

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1. Introduction

This research project investigates whether blockchain technology can be used to increase the funding of Nature-based Solutions. Nature-based Solutions (NbS) are natural solutions for coping with multiple sustainability challenges (Dorst et al., 2019). NbS can include climate adaptation, mitigation, increasing biodiversity, and improving social well-being. An example is the restoration of mangrove forests. The mangroves are used to protect coastlines from floods while at the same time this increases seafood prosperousness leading to benefits for biodiversity and human well-being. Additionally, setting up these projects creates jobs and provides economic benefits to the area (Tran & Fischer, 2017). This example shows how such projects can simultaneously create economic, ecological, and social benefits, with many more applications. Besides managing ecosystems, NbS are used for integrating green and blue infrastructure in urban areas and are applied to agricultural systems. This leads to a wide range of benefits, from providing clean air and cooling in our cities to improving human health and wellbeing (Seddon et al., 2020).

Although Nature-based Solutions can benefit multiple aspects of society, only 1% of the financing used for biodiversity conservation and even less of the water management budget is addressed to NbS (Deutz et al., 2020). To attract funding for implementing NbS on a larger scale is complex (e.g., Toxopeus & Polzin, 2021; Dorst et al., 2022; Mayor et al., 2021). Some barriers might explain why NbS is still only implemented to such a small extent, such as the assessment of nature's benefits (e.g., Naumann et al., 2011; Kotchen & Powers, 2006), lack of collaborative funding (e.g., Kabisch, 2015; Droste et al., 2017; Toxopeus & Polzin, 2021), and short-term investment horizons of investors (Toxopeus & Polzin, 2021).

Technology is often used to reach sustainability goals (Paredis, 2011). For financing sustainable development, financial technology (commonly referred to as fintech) seems to fill some gaps like transparency and verifiability (Machiavello & Siri, 2020). The authors mention applications such as crowdfunding and digital ledger systems. Furthermore, fintech supports sustainable development by reducing transaction costs and information asymmetry, enabling the valuation of nature, and promoting sustainable lifestyles (Cen & He, 2018). Additionally, a Chinese study showed that the development of fintech positively contributed to investment initiatives to protect the environment by increasing trust and tackling information asymmetries (Muganyi, Yan & Sun, 2021).

Blockchain, in particular, has been used for sustainability challenges in multiple ways. By looking at the application of blockchain in achieving the United Nations' Sustainable Development Goals (SDGs), Aysan, Bergigui, and Disli (2021) discovered that blockchain technology has been used to contribute to the majority of the 17 goals. To illustrate, the possibility of cross-border payments and a digital payment system has been used to fight poverty (SDG 1), improving transparency in supply chains has been used

to decrease food waste (SDG 2) and give farmers a fair salary (SDG 8), and micropayments through smart contracts have been used to facilitate small energy grids from solar panels (SDG 7). The main advantages of blockchain in these solutions are transparency, accountability, (peer-to-peer) value transfer, and cost reduction (Kawabata et al., 2019). Blockchain has also been beneficial for funding infrastructure projects in developing countries. These projects have commonalities with NbS as there is a lack of public funding available, insufficient public-private alliances, and the illiquidity of the projects makes the investment unattractive to private investors (Tian et al., 2020).

Blockchain technology's solutions could potentially help overcome the funding barriers to NbS. Previous blockchain-based solutions have shown the possibilities, and the first real-life cases are emerging. Toxopeus and Polzin (2017) also mention cryptocurrencies as potential financial innovation to find mechanisms that allow the funding of NbS. The main research question will therefore be:

How can blockchain technology be used to overcome funding barriers that hinder the implementation of Nature-based Solutions?

The main academic contributions of this research project will be in the field of Nature-based Solutions. Specifically, it will add to the literature on finance for NbS. Much has been written about the difficulties of funding NbS projects. This paper maps financial barriers to implementing NbS, sorting those out for multiple funding sources. Moreover, the research also adheres to the call for investigating the involvement of private actors in upscaling NbS (Toxopeus & Polzin, 2021).

Furthermore, the findings on the role of blockchain in funding such projects can open up new pathways toward developing ways to overcome similar challenges using this mechanism. Additionally, the research will contribute to blockchain literature, particularly in the 'blockchain for good' field (e.g., Aysan et al., 2021; Adams, Kewell & Parry, 2018); Eikmanns, 2018). Since blockchain is still in an emerging phase, showing the possibilities and benefits the technology has to offer can increase the speed and rate of its adoption.

The social relevance lies in the prospect of mainstreaming the implementation of NbS is promising given all the potential social, ecological, and economic benefits it has to offer. Alleviating the barriers to NbS finance can drastically increase the feasibility of such projects.

The remainder of this paper will be structured as follows. The literature review will be presented in the coming section, divided into two parts. First, existing knowledge about the NbS and the financing barriers of NbS will be laid out. Then the link will be made to blockchain technology and the possible solutions that it has to offer. These two concepts will be connected in the conceptual framework that

follows to sketch an overview of how blockchain-based solutions can theoretically alleviate financing barriers to NbS. Qualitative research will be conducted to answer the research question, and this approach will be explained in more detail in Section 3. This section contains the research methodology, describing the research method and data selection. The findings will be presented in section 4, followed by the discussion and conclusion.

2. Literature Review and Theoretical Framework

The literature review will be built up as follows. First, the term Nature-based Solutions will be introduced and further discussed in light of its related funding barriers. Next, the role of technology, specifically blockchain, in sustainability transitions shall be explained. This part will also discuss blockchain-based solutions for sustainability issues. Finally, the risks and challenges of blockchain technology shall be considered. The information will be linked by the conceptual framework presented at the end of the section.

2.1 Funding Nature-based Solutions

Existing literature mentions several definitions for Nature-based Solutions. Albert et al. (2017) phrase it as an umbrella term for bringing together similar ideas like ecosystem services, natural capital, and green infrastructure. Most Nature-based Solutions are focused on climate adaptation and mitigation, but other benefits include increased biodiversity, food security, and social wellbeing (Kabisch et al., 2016). NbS are multifunctional, meaning they deliver multiple services simultaneously (Droste et al., 2017). There are many forms that NbS can take, such as forests, coral reefs, parks, and green roofs. Furthermore, it must be mentioned that NbS can be located in natural *and* urban areas. In urban areas, NbS mainly targets restoring urban water bodies and developing green spaces (Hagedoorn et al., 2019). The multifunctional and diverse forms that NbS can take require a holistic perspective in governance, and this governance is primarily local as NbS are dependent on location (Dorst et al., 2019).

The European Commission (EC) believes that NbS can be used for inclusive, green growth. The EC considers NbS innovative and cost-effective solutions based on nature that can benefit multiple areas of our society, aligning with the plans toward sustainable development (European Commission, 2015). Cohen-Shacham et al. (2016) also highlight that NbS can provide benefits in multiple fields simultaneously, such as restoring and managing ecosystems while benefitting human well-being in the area. NbS benefits to human health and wellbeing are pretty significant. Van den Eeden et al. (2022) conducted a study of 5 million people in California and found that people who live in a green environment have significantly lower healthcare costs. On average, the extra greenery saved 300 dollars

per person, which, if you multiply that by the number of people involved in the study, can lead to enormous savings for the insurance industry and possibly a good incentive to invest in NbS.

Looking at all the promised benefits of NbS, one could be surprised that such solutions are not being implemented on a large scale. One of the critical barriers to upscaling NbS is the difficulty of obtaining finance (Toxopeus & Polzin, 2021). The coming subsections will discuss these financial barriers found in the existing literature. An overview is given in the table below.

Table 1. Funding barriers to implementing NbS

General	Public	Private
Benefits of nature difficult to assess	Silo mentality	Benefits of nature not priced in markets
Maintenance	Insufficient public resources	NbS represent local public goods
Lack of public-private alliances	Limited knowledge about NbS	Short-termism
	Short-termism	The innovative character of urban NbS
		Externalities in terms of knowledge spillover

2.1.1 General funding barriers

One of the challenges that Mayor et al. (2021) identified in funding NbS is the difficulty of determining its value, both monetarily and non-monetarily. Although the general consensus is that NbS, and nature in general, provide many benefits, there is still not a generally accepted method to quantify the value of these services. Additionally, the value of nature is often underappreciated (Naumann et al., 2011), making it even harder to find funding.

Another general barrier to funding and implementing NbS projects is that NbS need additional investments for maintenance and operational purposes, in addition to the initial investment (Mayor et al., 2021). If the project does not create revenue over time, this can hurt its economic sustainability.

2.1.2 Public funding

A lack of collaboration within public departments is often mentioned as a reason for the lack of public funding for NbS (Kabisch, 2015; Droste et al., 2017; Toxopeus & Polzin, 2021; Mayor et al., 2021; Dorst et al., 2022). This shortage of collaboration, or information sharing, within organizations is often referred to as a silo mentality (Mayor et al., 2021). The multifunctionality of NbS implies that the benefits and responsibilities of a single project can be scattered over multiple departments, all with their own goals and agendas. The challenge arises when departments work together to coordinate budgets for shared investments. In many cases, this information asymmetry results in projects not being funded.

Even if a public organization works collaboratively, there frequently remains a lack of knowledge about NbS (Toxopeus & Polzin, 2021; Dorst et al., 2022).

Overall, there are insufficient public resources to finance the large-scale implementation of (urban) NbS (Toxopeus & Polzin, 2021; Dorst et al., 2022). Besides limited knowledge and a silo mentality, short-term decision-making cycles have been pointed out as a funding obstacle (Toxopeus & Polzin, 2021). The benefits of NbS projects implemented now may only be visible in a few years. If public instances base their decisions on short-term gains, NbS projects will not be viewed as beneficial, even though its benefits may be found on a longer horizon.

2.1.3 Private funding

Seddon et al. (2019) found that poor financial models have led to underinvestment in NbS, especially in the private sector. This concern is shared by other researchers (Mayor et al., 2021; Dorst et al., 2022), who mentioned investors' short-termism as a reason. The payback horizon of NbS is long-term, and the assets are illiquid, which makes the assets unsuitable for trade. Furthermore, the economic growth orientation of private investors is not always pleased when investing in NbS, and the performance of such projects brings about uncertainty.

The innovative character of (urban) NbS is also mentioned as a barrier to private funding (Toxopeus, 2019). The literature on innovation science has shown market failures linked to investing in innovation. At the same time, there are externalities in knowledge spillovers that make the investment less attractive (Toxopeus and Polzin, 2021). Investing in a public good, such as NbS, means that others can benefit from that investment too. So, from that point of view, it could be beneficial for a private organization to wait for others to make the first move. In this textbook example of a prisoner’s dilemma, the utility of all parties involved will not be maximized as long as the information asymmetry persists.

Perhaps the most crucial reason for the level of engagement of the private sector in financing NbS is that investors do not reap ecological and social benefits (Dorst et al., 2022). These benefits are not priced into existing markets due to their public goods characteristics (Kotchen and Powers, 2006; Besley and Coate, 2003; Mayor et al., 2021). Finding a way to monetize and trade these non-monetary benefits could make the investment in NbS much more attractive.

2.2 Overcoming financial barriers to NbS

The literature on financing NbS offers some solutions to the challenges mentioned before by finding new or combined sources of finance. First, citizens are mentioned as a possible addition to the current investor base of NbS. Hagedoorn et al. (2021) investigated time contributions to decrease the monetary investment required for such a project. The authors found that the investment of time from local communities can reduce funding needs by 29 to 40%. This amount is explained by the fact that implementing NbS is typically highly labor-intensive (Ando et al., 2020). This decrease in financial needs can mean a difference in the possibility of starting an NbS project, but there will always be the need for a certain amount of finance. Citizen contribution as a possible additional source of finance to enable NbS could theoretically also come in monetary forms (Toxopeus and Polzin, 2021). To make this possible, funding NbS projects would need to be divisible over many investors.

The second and perhaps more feasible solution is a collaborative form of finance, where public and private actors engage in the co-funding of NbS. Balancing and coordinating the two sources of finance for a particular solution is challenging. Sustainable innovation routes, in general, involve both public and private actors. The public participants use policy measures, R&D co-investment, and trading mechanisms to help decrease the risks for private investors (Polzin, 2017; Droste et al., 2017). Developing instruments to initiate such public-private alliances to share risks and rewards could reduce private funding barriers (Toxopeus and Polzin, 2021). One financial innovation that has been put forward to initiate public-private collaboration is the further development of systems using cryptocurrency (Toxopeus and Polzin, 2017). Cryptocurrencies are operated on blockchain technology. The literature on this emerging technology will be discussed in more detail in the coming section.

2.3 Blockchain technology

Blockchain technology can be seen as a tool for revolutionizing the way we collaborate, organize, and govern organizations (Davidson, DeFillipi & Potts, 2016). For the readers not entirely familiar with blockchain terminology, a glossary is included in Appendix 1.

Initially, blockchain technology was created to fundamentally change the way we do finance by using cryptographic proof to avoid institutions (Nakamoto, 2008). Blockchain is a “distributed and immutable electronic database—a ledger of every transaction that has ever taken place on a network” (Howson, 2019). The data is stored simultaneously on all computers (nodes) in the network. The distributed mechanism mitigates the need for a central authorization to save or audit the information. The authorization happens through a decentralized consensus mechanism, where at least half of the nodes

must verify the correctness of the information before it can be put on the chain (Jiang, 2018). Since the autonomy to verify and accept information is decentralized, the power is divided among several independent entities (Constantinides, Henfridsson & Parker, 2018). This system allows for trust among stakeholders without a third party involved. Simultaneously, it can lead to cost reduction through decreasing administrative costs (Chen, 2018; Carson et al., 2018; PwC, 2018) and transaction costs (Carson et al., 2018; Kawabata, 2019; Oberhauser, 2019). Another significant benefit of the decentralized consensus mechanism is that the system is almost impossible to hack, thereby providing security for the contained data (Jiang, 2018; Friedlmaier et al., 2018).

Blockchain technology is already used for multiple sustainability purposes, referred to as blockchain-based solutions (Aysan et al., 2021). The solutions vary from fighting poverty to improving biodiversity, providing means for honest labor, and supplying clean energy (Aysan et al., 2021). Blockchain can be attractive for sustainability transitions because it can be used to find novel ways of funding. Blockchain-based governance mechanisms can improve monitoring and reporting, reduce fraud, and enable transparency in supply chains (Chapron, 2017; LeSève, Mason & Nassiry, 2018). The coming section will present the solutions that blockchain technology has to offer, including some practical examples.

2.3.1 Blockchain-based solutions

The table below gives an overview of the mechanisms that are enabled by blockchain technology. In the text, these mechanisms will be discussed in more detail.

Table 2. Blockchain-based mechanisms

Distributed ledger	Tokenizing assets	Smart contracts	Decentralized payment infrastructure
Information immutability and transparency	Fractional ownership	Autonomous enforcement of agreements	Global, cross-border payments
Trust	Crowdsource funds	Increased efficiency	Value transferring
Security	Tradable value		Peer-to-peer trading
Cost-reduction	Incentive machine		Democratize entrepreneurial finance

Perhaps the most innovative application of blockchain technology is asset tokenization. Asset tokenization is an extension of blockchain technology that allows real-life assets to be digitized and traded. It creates liquid and transparent financial systems that are globally available (Sazandrishvili, 2019). Tokens can be generated with blockchain technology and reflect various scarce goods (Fisch, 2019). This can be valuable when trading assets that are difficult or impossible to transport, such as forests or other NbS. The transactions of tokens, and thus ownership, do not have to mean transportation of the assets because the value is digitalized. Furthermore, tokenizing assets allows for fractional ownership and divisibility of large investments, which widens the investor base and increases accessibility to finance (Huang, Meoli & Vismara, 2020).

Tian et al. (2020) investigated the role of asset tokenization in funding infrastructure projects in developing countries, which have quite some similarities with NbS projects. The projects are challenging to fund due to a lack of public resources, issues with transparency, and low private sector engagement because of the low liquidity. The authors concluded that asset tokenization could increase funding for these projects from public and private investors. Smart contracts can improve efficiencies in governance through improvements in auditing and monitoring. Simultaneously, tokenization would increase the private investor base as it enhances the asset's liquidity and increases the number of investors that can step into a project (Tian et al., 2020).

Tokens can also be used as an 'incentive machine,' incentivizing individuals or organizations to show particular behavior in exchange for value in the form of tokens. For instance, this can be used to harness circular economies (PwC, 2018). Plastic Bank, for example, is a social enterprise rewarding individuals with tokens to collect plastic from the oceans in The Philippines and Brazil. Local communities benefit from the reward and a cleaner environment, and the company turns the plastic into usable assets (Plastic Bank, n.d.).

The second main feature of blockchain is machine-based automation, the technology that enables smart contracts (Lumineau, Wang & Schilke, 2020). Smart contracts use code to automatically verify and accept transactions under pre-set circumstances (Werbach, 2018). The main benefit is that it increases trust and efficiency by allowing for autonomous enforcement of agreements without needing a judiciary. An example of smart contacts can be found in Namibia, where a project was set up to pay the local community for the regeneration of ecosystems. Monitoring the environmental capacities was done using smart contracts linked to remote sensing algorithms to automatically enforce the payments based on the condition of the environment. This reduced the transaction costs and increased the efficiency of the ecosystem payments (Oberhauser, 2019). In another case, smart contracts were used to automatically mobilize public and private organizations to aid local communities in case of a natural disaster (PwC, 2018). This improves the effectiveness of such operations.

Thirdly, blockchain offers a decentralized payment infrastructure that allows for transferring value globally without an intermediary. In this sense, value can take many forms, such as valuable information, monetary value, property rights, titles, etc. (Tapscott & Tapscott, 2016; Ito, 2016; Kawabata et al., 2019). The system enables cross-border payments (Aysan et al., 2021) and peer-to-peer trading networks (UNFCCC, 2015; Wright and De Fillipi, 2015; PwC, 2018) to work more effectively and less costly due to alleviation of information asymmetry. Some even argue that blockchains' decentralized payment structure democratizes entrepreneurial finance by making funding available to ethnical minorities and entrepreneurs in geological areas less attractive to investors (Fisch et al., 2020).

2.3.2 Blockchain risks and challenges

Even though blockchain can be used to offer these benefits, it is crucial to be aware of the risks and challenges that come with this disrupting technology. Probably the most well-known critique of blockchain technology is its tremendous energy consumption. Bitcoin nowadays uses as much energy as the whole of Sweden (Cambridge Centre for Alternative Finance, 2022). This is due to the consensus mechanism that Bitcoin uses, called proof-of-work. The algorithm takes enormous computing power to verify the new information, making it safe but energy-intensive. Other, more commercial applications of blockchain technology take up significantly less energy by using other validation processes, like proof-of-stake or proof-of-authority (Ge et al., 2017; Chen, 2018). It is therefore essential to realize that energy consumption is not a general blockchain problem but a Bitcoin problem.

Another sustainability-related issue is that environmental blockchain applications can overlook other social problems by oversimplifying the situation (Börner, Baylis & Corbera, 2017). Blockchain is sometimes described as "*a few self-serving white men pretending to be messiahs for the world's impoverished, marginalized, and unbanked masses that claim to have created billions of dollars of wealth out of nothing*" (Roubini, 2018). The author poses that blockchain may increase social inequality by empowering white men and expanding the wealth gap. Oberhauser (2019), who analyzed the role of blockchain in payments for ecosystems in Namibia, finds a similar conclusion. He found that the technology would potentially lower costs and increase efficiency if it were accessible to the right stakeholders, but the implementation of blockchain-based smart contracts in developing countries is unlikely due to the inaccessibility of technology. Howson et al. (2019) argue that blockchain is used for capitalist gains rather than beneficial socio-economic outcomes. Howson (2020) also expresses concerns about potential crypto-colonialism, where developed countries use data and surveillance to deepen the inequalities between the global North and South.

On the other hand, much literature points out that blockchain can also have substantial social benefits. Aysan et al. (2021) show the use cases for blockchain concerning the SDGs, PwC (2018) explain how blockchain can be used for a better world, and Fisch et al. (2020) argue that blockchain can democratize entrepreneurial finance. So, although we should be warned of the potential social risks, Roubini's (2018) description may not tell the whole story.

Thirdly, legal challenges can arise from using blockchain. Blockchain is decentralized and, therefore, inherently global (Tapscott & Tapscott, 2016). This causes difficulties from a legal and regulatory perspective because, for example, there are still unclear legal jurisdictions (PwC, 2018). Furthermore, it is for most blockchain applications still relatively easy to stay anonymous. This has led to criminals

being able to launder money without being caught. As with any disruptive innovation, legal entities are behind when it comes to new rules and regulations.

2.4 Conceptual framework

The funding barriers that hinder the implementation of NbS, as found in the literature, can essentially be divided into three categories: (1) lack of knowledge about NbS, (2) inefficient governance, and (3) small investor base. The difficulty in assessing nature's benefits, limited knowledge about NbS within municipalities, and externalities in terms of knowledge spillover can all be placed in the first category. The inefficient governance is caused by a silo mentality within municipalities and the need to maintain NbS projects. Thirdly, the lack of finance exists because the investor base for NbS is relatively small. There is not much public funding available, the private sector is not engaged, and there is a lack of collaboration between the two.

Potentially, blockchain technology can positively influence the funding of NbS because it can be used to increase the investor base and make existing governance processes more efficient. Tian et al. (2020) give an excellent example with their research on how asset tokenization can increase funding for infrastructure projects in developing countries. They found that smart contracts can automate auditing and monitoring processes, thereby increasing efficiency and lowering costs. Furthermore, fractional investments and ownership increased the private investor base. Blockchain's ability to create trust among stakeholders can open the doors for new public-private alliances, where the risks are spread out more evenly. To collaborate, investors do not need to be from the same country as the blockchain allows for borderless transactions of value. The literature does not mention the relation between blockchain technology and the gathering of knowledge, although the immutability of information stored on the blockchain could be a good way of collecting the available data.

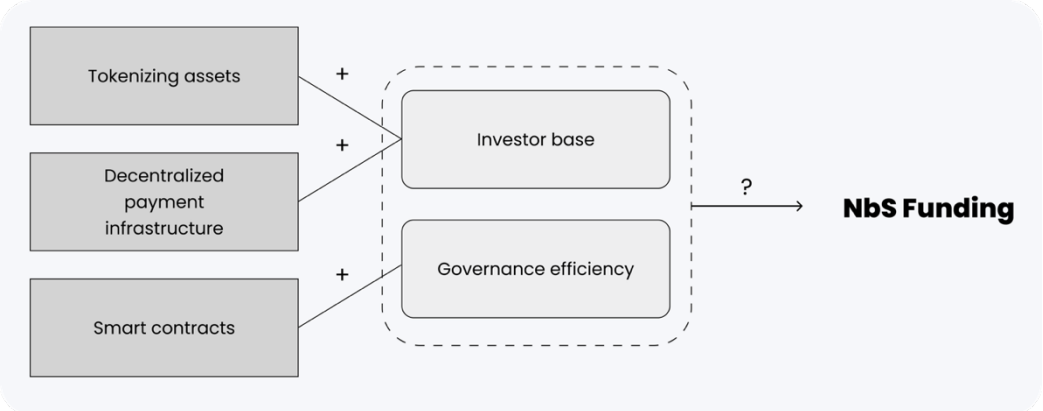

Figure 1. Conceptual framework of how blockchain can influence NbS funding

3. Methodology

Qualitative research has been conducted to find out if blockchain technology can be used to increase funding for Nature-based Solutions. To ensure the trustworthiness of the analysis, this research project used data triangulation across multiple sources (Roome & Louche, 2016). The primary data source is semi-structured interviews conducted with various actors and organizations already working on using blockchain technology for the benefit of nature. These are complemented by interviewing specialists in the field of NbS and blockchain, respectively. Furthermore, secondary data from online interviews and consultancy- and company documents is collected and investigated. Third, fieldwork has been done to gather data from a more practical point of view. This fieldwork was conducted by participating in five online sessions organized by companies that use blockchain to obtain funding for NbS projects.

3.1 Data Collection

As mentioned, data was collected in three ways to ensure the validity of the findings. The coming section will explain in more detail what type of data is gathered and how the data collection was done.

3.1.1 Secondary data

Archival data has been selected from several sources. First, three white papers were collected from companies operating in blockchain and NbS funding. These white papers explain in detail the mechanisms these companies use to operate their business. The information in the white papers has been apprehended before the interviews to prevent asking double questions. An example from the white papers is the one from Open Forest Protocol (OFP). OFP has built a platform that provides access to funding for forestation projects worldwide by creating a standardized and accessible monitoring system. The white paper explains in detail how these systems work and technology's role in the system. Someone from the company has been interviewed for follow-up questions.

Secondly, a comprehensive review of five research documents has been conducted. The documents included studies that investigated the possibilities and barriers of using blockchain technology for the funding of nature. More documents were initially collected, but those were not selected for the data analysis because they either did not convey information on the topic or the source was not trustworthy enough. When searching for data, the quality of the sources will be assessed on the following criteria: it must have an authentic origin, be credible, representative, and comprehensible (Scott, 1990). The organizations behind it are well-known and trustworthy, such as the UN Environmental Program and the Green Digital Finance Alliance.

Thirdly, two online interviews have been transcribed and used as a secondary data source. The interviews contained some valuable information from organizations that were not available for an interview for this research project. The interviews included a podcast with the founder of Nature4Climate, an organization working with NbS for climate mitigation projects. The second is an interview with the founders of Single Earth, one of the leading companies in using blockchain for funding nature conservation. A complete overview of all data can be found in Appendix 3.

3.1.2 Semi-structured Interviews

Interviews were conducted to find objectives that are otherwise difficult to observe. The objects of investigation are the actors and organizations that use blockchain to fund nature and NbS, complemented by experts in these fields. The interviews were conducted between April and June 2022 and guided by the researcher. The process started by creating a long list of potential interviewees through a comprehensive internet search. Appendix 2 includes the long list of organizations and experts that have been approached for an interview. Most of the organizations and experts on the list were approached by email and, in case of no response, sent a reminder through LinkedIn. Unfortunately, the response rate was much lower than expected. In total, six interviews were conducted that are presented in the list below.

Table 3. Interviewees

Code	Organization	Role
Interview A	Internet of Nature	Founder
Interview B	Open Forest Protocol	Funding Manager
Interview C	TreeCollective	Co-Founder
Interview D	Winding Tree	Blockchain Expert
Interview E	Regen Network	Grants Manager
Interview F	Circular Finance Lab	Founder

A semi-structured interview style is used to encourage flexible conversations with the interviewees. One of the advantages of using semi-structured interviews is the richness of answers that it generates, as respondents can talk more freely (Harvey & Long, 2001). An interview guide has been prepared to answer the research question, which can be found in Appendix 4. The interview guideline makes sure that the necessary information is collected (Herriott & Firestone, 1983). The main topics of the interviews are presented in the figure below. The types of interviewees can roughly be divided into two groups: organizations that are helping to implement NbS (using blockchain) and blockchain/fintech experts. For both groups, a different approach will be used as they have different types of knowledge, but the final topic of these approaches will be similar. The arrows in the figure point out the two different

paths toward the same topic. Approaching the research question from different angles allows for a broader overview of possible solutions. Full transcripts of the interviews are available upon request.

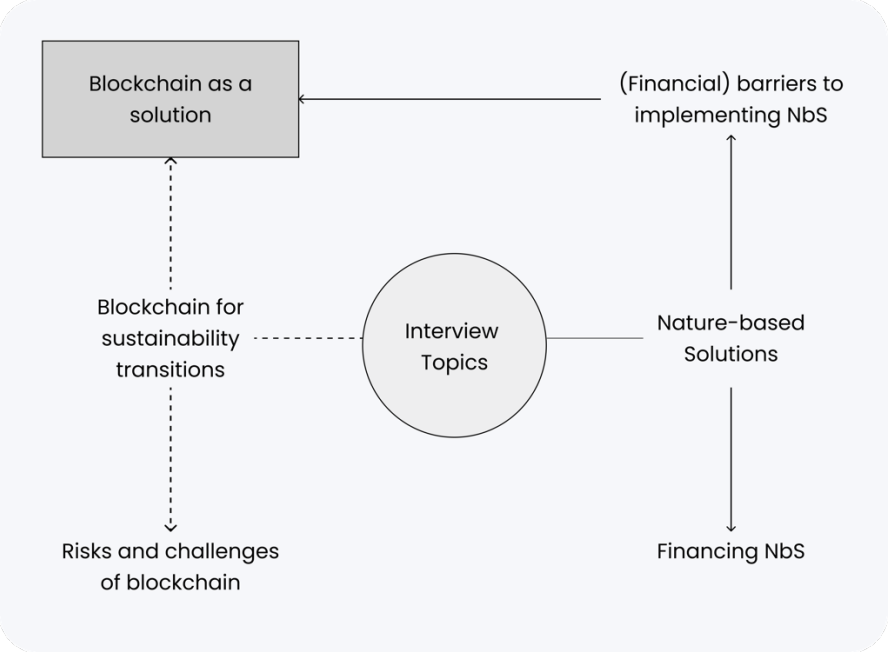

Figure 2. Interview topics approached in two ways

3.1.3 Fieldwork

To complete the data triangulation, additional fieldwork in the form of participant observation has been conducted. Participant observation allows the researcher to observe and participate simultaneously, providing unique insights into the system under investigation (Rock, 1979). The fieldwork consists of four sessions held by Toucan Protocol and one session organized by Single Earth. Both organizations are leading actors in the upcoming space of using blockchain-based mechanisms to attract funding for NbS projects. The sessions were conducted online and were open to anyone who wanted to join. During the sessions, questions could be asked to the participants using the chat function, and the moderator would read those out. This allowed for asking some specific questions for this research project. The participation was done anonymously and without notice of the research project to ensure the researcher would not influence the sessions.

The limitation of this approach is that the sessions were organized by the blockchain-based organizations and were probably followed by people who know the sector too. This could lead to a bias in the opinions or information shared. Nonetheless, the triangulation approach allowed for data collection from multiple perspectives leading to increased robustness and validity of the findings (Creswell & Miller, 2000). The researcher notes that the fieldwork sessions are available upon request.

Table 4. Fieldwork sessions

Code	Session	Participants
Session A	Toucan Office Hours 10-05-2022	Toucan Protocol
Session B	Toucan Twitter Space 18-05-2022	Toucan Protocol, Solid World DAO
Session C	Toucan Office Hours 24-05-2022	Toucan Protocol
Session D	Toucan Twitter Space 08-06-2022	Toucan Protocol, Regen Network, Open Forest Protocol, Moss Earth
Session E	Single Earth 'Ask Me Anything' 16-06-2022	Single Earth's founders

3.2 Data Analysis

The interviews were recorded with the permission of the interviewees. To fully capture the sentiments and experiences of the interviewees, these recordings were used to transcribe the interviews word by word (McLellan, MacQueen, & Neidig, 2003). The interviews, including the interviews from secondary sources, have been transcribed using Descript, a software for transcribing mp3 and mp4 files. Interview C was conducted in Dutch and afterward translated to English using DeepL to better compare the results with the other interviews. Interview F was also conducted in Dutch, but the interview was not recorded. However, sufficient researcher notes from this interview are used for the data analysis. The gathered data is analyzed using NVivo software, developed to analyze qualitative data and mainly used for coding. All data, including secondary documents, were uploaded on NVivo for coding.

The data is structured according to the framework of Gioia, Corley, and Hamilton (2013), where different dimensions of the data are abstracted to find patterns. These extra dimensions can be discovered in the data because the analytical process used open coding (Strauss & Corbin, 1988). The framework is divided into three steps. The first-order concepts are written in terms of the informants and often contain many different categories. Boiling this down into second-order concepts, using researcher dimensions, is used to give more grip on the data (Gioia et al., 2013). This process relates categories to their subcategories, also called axial coding (Strauss & Corbin, 1988). Once the concepts were "theoretically saturated" (Glaser and Strauss, 1967), aggregate dimensions were derived. This was done by reducing the number of categories even further. A data structure was built by combining the 1st order concepts and 2nd order themes and dimensions (Corley & Gioia, 2014).

The first categorization of the coding structure is done a priori, as some information was already found in the existing literature. A codebook was created based on the literature review and theoretical framework to allow for a more structured approach to coding the data. The second categorization, which is also added to the codebook, was identified a posteriori. Coding is essentially a circular process where

the researcher may return to the raw data when new information is found, and this is also how the code book developed during the analysis (DeCuir-Gunby, Marshall & McCulloch, 2011). The complete codebook can be found in Appendix 5. The entire data structure can be found in Appendix 6, an example shown in the figure below.

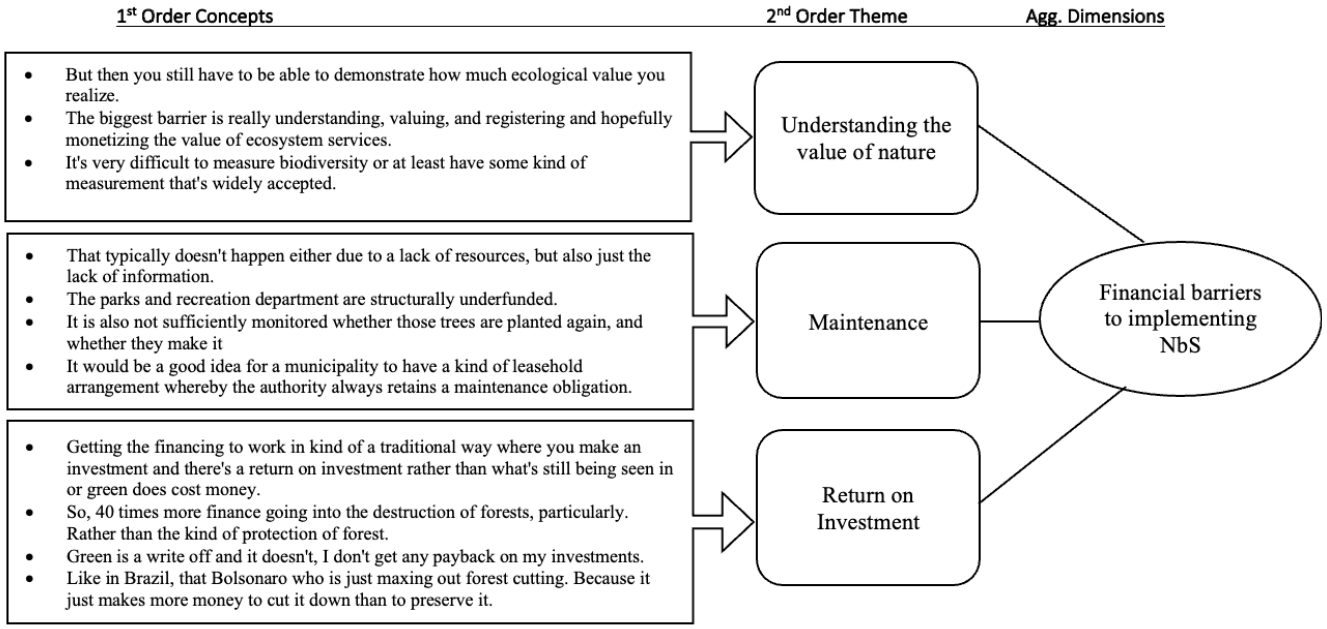

Figure 3. An example of the coding structure

4. Findings

Section 4 will present the research findings based on the interviews with experts, secondary data, and the various fieldwork sessions. It will answer the research question by looking at the blockchain-based solutions for the funding barriers to NbS. First, the primary funding barriers will be discussed, followed by two mechanisms that will be presented that use blockchain to solve these challenges. Next, the text will elaborate on how carbon sequestration is used as a proxy for nature's value and what might be the benefits and downsides of this method. The last subsection will show some additional findings that might not directly answer the research question but are insightful for the overall picture.

4.1 Blockchain-based mechanisms for funding NbS

The findings show that there are three main barriers to funding NbS: (1) meeting the risk-return requirements of investors, (2) monitoring and maintaining NbS, and (3) understanding and monetizing the benefits of nature. Let us start with the first. Apart from some philanthropic financiers, most private investors require a return on investment for their funding. In the case of NbS, this has proven to be

problematic in the past. Nature offers countless services and benefits to our society, but most of these do not generate a financial return directly. If we want to sustain and regenerate our nature, instead of destroying it at the current pace, we might have to find a way to make it financially attractive (Interview C). Whether we like it or not, money makes the world go round. Interview C exemplified this by mentioning the destruction of the Amazon Forest:

"Like in Brazil, that Bolsonaro who is just maxing out forest cutting. Because it just makes more money to cut it down than to preserve it." (Interview C, min. 26)

We must find a way to get the financing to work in a traditional way where there is a return on investment and investors will view green more as an asset rather than a cost (Interview A).

The second funding barrier to implementing NbS is the cost and effort of monitoring and maintaining the projects. Monitoring often does not happen due to a lack of funding or simply a lack of information (Interview A). This has two negative consequences: (1) Not maintaining NbS can lead to the natural solution not surviving, especially in urban areas (Interviews A). (2) If projects are not monitored in a transparent way, investors will not receive a proof of impact, which may lead to significantly lower amounts of funding (e.g., Document F), and this monitoring should be done efficiently to make it financially feasible (i.e., Document C). Blockchain, in combination with other emerging technologies, is often used to overcome this barrier.

The third and perhaps the most significant barrier to funding NbS projects is our disability to value and monetize the benefits of nature. As Interview A put it:

"The biggest barrier is really understanding, valuing, and registering and hopefully monetizing the value of ecosystem services." (Interview A, min. 1)

People sometimes tend to forget that we are all part of an extensive ecosystem, and nature offers countless services to this ecosystem to keep it running. These services are beneficial for climate adaptation and mitigation purposes but are also crucial for human health and wellbeing (e.g., Interview G). To implement these services in a business case for NbS, the benefits must first be understood and measured before being translated into monetary value. Some companies and researchers are already advancing in this field with the help of technology. Interview A mentioned iTree, an organization that measures ecosystem services of trees and parks such as rainwater filtering, air quality, and cooling of our cities. These benefits indirectly have monetary value, such as preventing water damage from heavy rainfall and decreasing the amount of air conditioning needed in warm summers. Interview C provided

another example. They found that cows give more milk if trees surround them. This could provide a financial incentive to farmers to plant trees on their acres.

Still, there is no widely accepted measure for assessing complex matters like biodiversity (e.g., Interview B). Single Earth is a blockchain-based company working on a standard for measuring biodiversity and ecosystem services and plans to release that this year (Single Earth, n.d.). Until a system is found that scientists agree on, carbon sequestration will be used as a proxy for the benefits because that can be measured in ways that are globally accepted.

A model has been derived from the data analysis that visualizes in what ways blockchain technology can be used to overcome these financial barriers to implementing NbS. The theory will first be explained shortly before zooming in on the different building blocks of the model. The tokenization of natural assets is the first blockchain-based mechanism used to overcome NbS funding barriers. Tokens allow fractional investment and ownership, improving the assets' liquidity and tradability (e.g., Document C). This helps with meeting the risk-return requirements of investors.

Furthermore, the tokens incentivize landowners and communities to maintain NbS. The second mechanism, digital Monitoring, Reporting, and Verification (MRV) systems, combines multiple technologies to achieve efficiency and transparency in monitoring and auditing NbS projects. One of the main funding barriers not solved by these mechanisms is the lack of ability to understand and monetize the benefits of nature. Since there is no widely accepted standard for measuring all the benefits, carbon sequestration is often used as a proxy. This is a good way of collecting funding but also has its downsides.

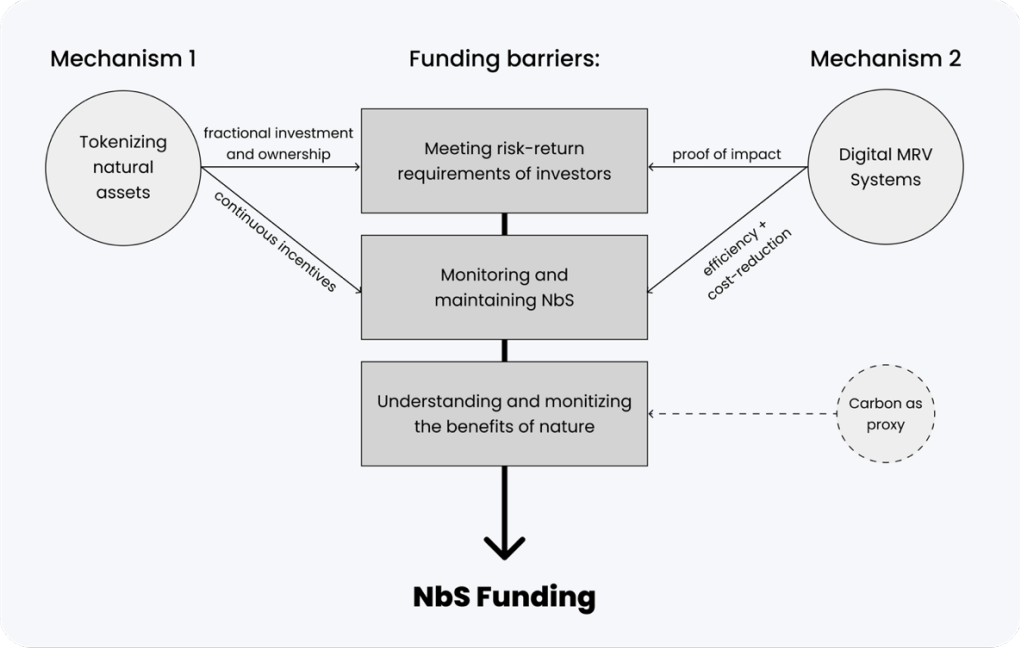

Figure 4. Blockchain-based mechanisms to overcome funding barriers of NbS

4.1.1 Mechanism 1: Tokenizing Natural Assets

One mechanism to attract funding for NbS is the tokenization of natural assets. By digitizing real-life assets, such as a piece of land, it can be traded on the blockchain. This creates an efficient and transparent financial system that allows fractional investment and ownership (Document E). It can be used to exploit or create a business model behind the implementation of NbS, thereby making it feasible for investors to step in (Interview C). If that can be accomplished, nature will be viewed as an asset rather than a liability, and the fund will be seen as an investment rather than a cost. In Interview H, the tokenization process was described as the creation of a 'digital twin':

> *"Blockchain gives us. It gives us a digital twin kind of representation of those values, and we can trade them."* (Interview H, min. 3)

Fractional Investment and Ownership

At the core of asset tokenization lies the possibility of fractionalizing an underlying asset's investment and ownership (e.g., Document D). This improves liquidity and increases the investor base, lowering the risks for investors and making the assets more tradable (e.g., Document C). The findings from the data analysis show that blockchain can improve the liquidity and scale at which natural assets can be traded. Through asset tokenization, a digital twin can be created that represents the values of the underlying natural asset, and we can trade them (Interview H). Being able to trade the tokens also gives it a speculative value created by investors who bet on the value of the underlying asset going up over time. Interview D already mentioned that this is happening in the market for carbon tokens, saying that holding these tokens gives an investor the main return on investment. Interview H similarly notes that the value of nature will only increase over time because "*with climate change and biodiversity loss nature will become the most valuable thing on the planet*" (min. 8). Selling the values of nature can be used to collect the funds needed for NbS projects at scale in a transparent way:

> *"Issue tokens and let's say have a very like transparent and safe way to do crowdfunding enables you to like coordinate at scale you know with, with a number of people and also in a larger geographical area."* (Interview D, min. 3)

This mechanism can be helpful for large projects that want to fractionalize the investment to increase the investor base, such as trading large plots of land in smaller pieces (Interview H). Even for smaller-scale projects, asset tokenization can be useful, as shown in this quote from Document C:

"Smaller biodiversity projects should seek to tokenize biodiversity assets: Projects too small for traditional financing methods should take advantage of blockchain's ability to improve liquidity and access more significant markets." (Document C, p. 4)

It does not matter what the project size is when it is traded on the blockchain, as there is no need for an intermediary service to oversee the transactions. This is a different case for monitoring and verifying the project, which will be discussed in section 1.1.2.

Besides trading the assets fractionally, blockchain also enables the registration of multiple different owners (Interview A) due to the transparent and immutable character of the technology. Furthermore, there is no need for an intermediary, making the process more efficient and significantly reducing transaction costs (e.g., Document D). The underlying figure gives a simplified visualization of how the tokenization of natural assets works. The value is encrypted on the blockchain, which can be divided into any number of tokens. The tokens can be owned and traded globally.

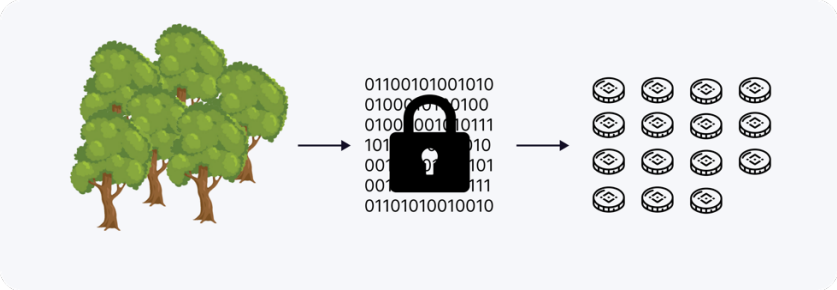

Figure 5. Tokenizing natural assets

Continuous Incentives

Another solution that asset tokenization offers is its function as an incentive machine. Tokens can be used to create incentives for desired behavior continuously. In the case of NbS, it is used to reward landowners for good stewardship of nature on their property. The Open Forest Protocol mentions the game theory that is built into their system:

"In essence, it's a lot of game theory built into it, (…) set the reward mechanisms or the punishment mechanisms using blockchain and using our own token OPN to incentivize good behavior and punish bad behavior. That's the power that blockchain can provide."
(Interview B, min. 11)

And in Fieldwork Session E, the Single Earth co-founder talked about how their system is designed to reward landowners for the long-term protection of nature continuously:

"We create a revenue stream based on the ecological state of land, this incentivizes the landowner to protect and regenerate nature." (Fieldwork Session E)

The mechanism can also incentivize whole communities to co-operate in a project and participate in the network (Interview D). An excellent example is GainForest, a blockchain-based platform that incentivizes indigenous communities to conserve and protect forests. By using smart contracts, the platform automatically transfers funding in the form of tokens to these communities when monitored that certain thresholds are met. These tokens can be used to unlock payments from a decentralized fund (Document H). The funding is collected from investors who buy a so-called 'NFTree,' a non-fungible token that represents the natural values of a restoration project. The owners of an NFTree essentially own a fraction of the restoration project. The NFTree holder automatically transfers a stewardship fee to the conservation projects to contribute to their governance. This token system allows for a sustainable funding stream for such projects and communities. To ensure financiers that their investment is spent on the project, data from AI systems and monitoring devices are uploaded on the blockchain to provide proof of impact.

4.1.2 Mechanism 2: Digital MRV Systems

Many organizations operating in the space of blockchain and NbS have made it their primary objective to efficiently monitor and audit NbS projects using Monitoring, Reporting, and Verification (MRV) systems based on blockchain, AI, and monitoring devices (e.g., Document D). Digital MRV systems are machine learning-based impact verifiers that leverage satellite, drone, and field data to recognize ecological changes (Document H). This mechanism offers mainly two solutions. First, it establishes trust and transparency by uploading real-time data directly on the blockchain. Secondly, the process is much more efficient because it uses technology instead of some middlemen that have to monitor, audit, and verify the data. These benefits will be discussed more in-depth in the coming subsections.

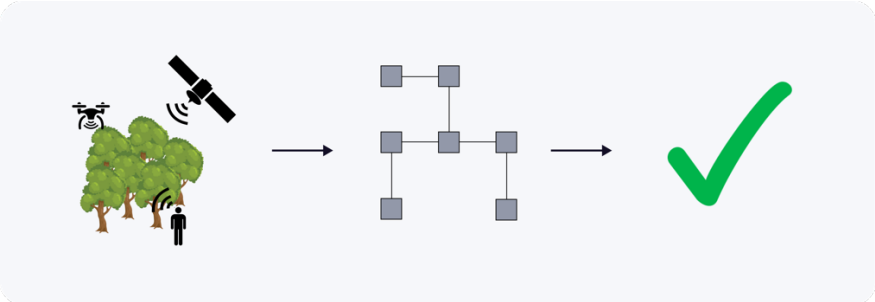

Figure 6. Digital MRV system linked to the blockchain

Establish Trust Between Stakeholders

Blockchain's promise of being a 'trust machine' is that it can improve transparency and accountability (Document E). This is especially valuable in systems where stakeholders do not know each other (Interview F), which is most often the case in the crowdfunding space for NbS. As Interview G mentioned, it can be used to alleviate the skepticism about the benefits of NbS by measuring those and uploading them on the blockchain:

"And rightly a lot of skepticism about Nature-based Solutions can be permanent, whether they can bring benefits to the community. And we felt that one possible way to help build that trust would be the proponent of technology in the right way and in the right kind of help create transparency, accountability, and monitoring, measuring all the things that people have been saying." (Interview G, min. 16)

Efficiency

Recording the entire MRV process on-chain can address the problems of trust and accessibility, as was mentioned in Fieldwork Session D. Trust comes from the way blockchain is designed, as discussed before. The accessibility that digital MRV brings is because of lower barriers to entry. The process is much more efficient and at lower costs, making it more feasible for regeneration projects to apply for funding. Document D confirms the lower costs by pointing to a study that showed that blockchain-based green bonds are ten times more cost-efficient than bonds that require an intermediary. Interview B added the note that the efficiency of this mechanism is helping to avoid greenwashing:

"By using new technology, you can really reduce the expense and time required for each validating. So, if you want to avoid greenwashing, that's the main job." (Interview B, min. 9)

The improved efficiency and cost-reduction allow smaller projects to be audited and verified, whereas that was not always feasible with previous methods (e.g., Interview B). And although the organizations investigated for this research all work on projects outside of urban areas, this mechanism can theoretically also work in cities. As the co-founder of Single Earth answered this question asked by the researcher in Fieldwork Session E:

"Yes, but we would need to build another mechanism/model around it. At first, it is based on scale. Let's say if you want to put all green roofs on L.A., then yes, we can talk. But if you just want to plant a tree in your garden we would need to wait for a new model." (Fieldwork Session E)

So, we can measure an area's ecological state by counting the number of trees or the average height of plants. We can make this information transparently available through blockchain, which receives data from automated data sources for the needed efficiency. These measurements can be linked to investments that automatically pay out if certain conditions are met. Still, there is no standardized method for measuring and capturing all the benefits of nature, let alone monetizing these values.

4.1.3 Carbon as a proxy for nature's value

Most companies operating in the space of blockchain and NbS are active in the voluntary carbon market. According to Fieldwork Session D's participants, the carbon market is meant to drive the funding needed toward projects that make a planet-positive impact. Most funding is obtained from companies that want to neutralize their carbon emissions by buying these carbon tokens. As mentioned earlier, carbon tokens are also interesting for investors that speculate on their price increase in the future (Interview D). Given the possibilities, this has been a good way of collecting funding for NbS projects. Carbon sequestration can be measured in widely accepted methods, and companies are willing to pay for it. However, focusing on carbon alone might make us forget the natural world around us. In the words of Interview H:

> *"So far carbon has been a very good equivalent for calculating nature. (…) The greenhouse gas measurements save us from overheating, but we don't want to be on this cool blanket ourselves without other species around us."* (Interview H, min. 6)

Problems with the carbon market

Even though the carbon market has the ability to collect funds for NbS, there are still problems with optimizing for carbon sequestration. If we optimize for carbon, we might neglect all the other benefits of nature while these might be far more important. Interview A would not even put carbon in the top 10 of NbS benefits:

> *"Carbon sequestration is not even in like the top 10 of different ecosystem services that that nature-based solution is going to offer."* (Interview A, min. 2)

In line with this statement, in Fieldwork Session E, it was mentioned that we cannot value nature only based on carbon sequestration:

> *"Nature is not a carbon machine; we can't value nature only based on the carbon it sequesters. We have to look at all the other benefits of nature to really value it."* (Fieldwork Session E)

Optimizing for carbon might even have negative consequences for other social and ecological challenges. Interview D brought up the adverse effects of a monoculture on biodiversity:

> *"How can you measure biodiversity? Because in the end, you're just going to like, create a monoculture for carbon credits. Like that's not great either. You need to think about, you know like mimicking nature again. If you're really like thinking long–term."* (Interview D, min. 19)

4.2 Additional findings

The coming section will present some of the additional findings that might be interesting to consider. These findings do not directly answer the research question but came up during the interviews and fieldwork sessions.

4.2.1 Inclusiveness paradox

The first additional finding will be referred to as the 'inclusiveness paradox' of blockchain technology. On the one hand, blockchain is deemed to be highly inclusive due to its decentralized structure. All the information is openly available to everyone, and anyone can participate in the network. This should create a global inclusion:

> *"Decentralized Access and Global Inclusion: By definition, an open protocol provides the technical basis from which any stakeholder can participate in a forestation process."* (Document G, p. 9)

On the other hand, there is a severe knowledge gap between people used to working with blockchain and those not. If many people do not know what the technology does or how to work with it, how inclusive can it be? Someone in Fieldwork Session D pointed out how difficult the technology can be to understand, even for people that work at one of the biggest tech companies in the world:

> *"We also have good ties and talks with big corporates, like Microsoft. When we have conversations with these companies, we have to realize that we are very well educated in this field, whereas they might not yet see the value of blockchain."* (Fieldwork Session D)

Another participant added that he did not understand the space either when he entered, but that it can be apprehended quite quickly:

> *"I remember entering the whole blockchain/crypto world and wondering "what are these people talking about?" But there is a pretty steep learning curve."* (Fieldwork Session D)

Additionally, it was mentioned in Fieldwork Session E that one of the main challenges of implementing their business model is to make the software understandable and user-friendly for all stakeholders.

4.2.2 Blockchain is no magic bean

The second additional finding is about the hype around blockchain technology. Many people adore the technology in a way that they tend to overestimate what it can do. Interview A mentioned that technology is a tool and should never be the goal. Interview D acknowledges the benefits that blockchain can offer but also emphasizes that it can take the focus away from the real purpose:

"It's very powerful and it's nice, but sometimes it, it takes up all the focus and that's the problem"
(Interview D, min. 19)

Blockchain technology is a tool for storing and transferring information, and it can do so safely and efficiently. This does not take away the fact that the data used as input can still be misleading or fraudulent, even though there is a decentralized consensus mechanism in place. As stated in Fieldwork Session D:

"Garbage in, garbage out. Blockchain by itself cannot access the correctness of data input."
(Fieldwork Session D)

5. Discussion

The findings show that tokenizing natural assets and digital MRV systems are two blockchain-based mechanisms that can be used to overcome funding barriers that hinder the implementation of Nature-based Solutions. The two mechanisms are aligned with both axes of Toxopeus & Polzin's (2021) framework of barriers and strategies for urban NbS finance. The vertical axis represents the coordination barriers across public and private financiers. As concluded by the authors, a key strategy to overcome this barrier is the innovation of financial instruments that enable public/private risk-sharing. The crowdfunding system created by tokenizing natural assets could be a good instrument as it allows to spread the risk among many different investors. The horizontal axis represents the valuation and accounting barriers for capturing the multiple NbS benefits. One of the critical strategies that Toxopeus & Polzin (2021) found is to improve data, evidence, and metrics through technological developments. The MRV system explained in the findings as Mechanism 2 can adhere to this strategy by making the

data gathering more transparent and efficient. Translating this into a widely accepted accounting framework would be an excellent next step.

Another funding barrier that Mayor et al. (2021) discovered is the investment that NbS need along the way for maintenance. The findings of this research show that tokens can be used to incentivize landowners and communities to maintain an NbS project (e.g., Document H). Smart contracts are written to automatically transfer donations in the form of tokens to these land stewards once the digital MRV system identifies that preset conditions are met. This mechanism enables the investment needed for maintaining NbS, helping to overcome this funding barrier.

The tokenization of natural assets also allows for fractional investment and ownership (Huang et al., 2020). This improves the tradability and liquidity of the assets, resulting in the attraction of more private funding. As Mayor et al. (2021) and Dorst et al. (2022) concluded, investors' short-termism is one of the main reasons there is a lack of private funding for NbS. Being able to buy and sell the assets (i.e., tokens) can alleviate this uncertainty. It can also generate a return on investment for investors if the value of the tokens increases over time. This speculative value increase of tokens is described as the primary return for an investor by Interview D. Having a return on investment helps attract private investors. Still, there are also dangers to putting a speculative price on nature. A famous example of how speculation about the value of nature can go wrong stems from The Netherlands in the 17th century. The Tulipmania took place between 1634 and 1637 when a bubble was created around the value of tulip bulbs. Large amounts of funds entered the country, but in February 1637, the frenzy was suddenly terminated, and the tulip bulbs dropped to 10% of their value leading to long-term economic difficulties (Garber, 1989). This does not mean that the same will happen to the tokens with nature as underlying value, but it should still be considered a severe warning.

On a positive note, fractional investment increases the investor base *and* opens the possibility for citizen funding. Toxopeus and Polzin (2021) mentioned citizen funding as a possible additional source of finance for NbS if the investment was divisible over many actors. The token mechanism is highly suitable, as it allows the investment to be split into countless pieces without extra paperwork or transaction costs. Moreover, the decentralized consensus mechanism secures the transactions, generating trust among investors without them knowing each other. Essentially, thousands of investors from all over the world can collaborate to fund one small NbS project. This might be able to take away the worry of Seddon et al. (2019) that poor financial models cannot engage the private sector. Tokenization also allows for new financial models for NbS, such as what Single Earth is doing by using the tokens to incentivize landowners to protect nature on their land.

The findings on Mechanism 1 show similar benefits to the conclusions from Tian et al. (2020) in their study on funding infrastructure projects in developing countries. It turns out that the benefits found for these projects also apply to NbS projects. Tokenization increases the investor base for both sectors by improving liquidity (e.g., Document C), simultaneously making it more accessible to smaller projects (e.g., Document G). Fractional investment is mentioned in both documents as a reason for the increased engagement of private investors. The findings on Mechanism 2 also align with the results of Tian et al. (2020), in a sense that smart contracts improve the efficiency of monitoring and auditing the projects (e.g., Interview B). The results of Tian et al. (2020), however, link the monitoring improvements to an increase in public finance. In contrast, the findings of this research project link the benefits to the carbon market, which is dominated by private funding. The findings of Tian et al. (2020) are a sign that Mechanism 2 can increase public financing for NbS, but future research should investigate this issue.

The model does not explicitly target the lack of public funding that came forward in the literature review. In fact, the blockchain is designed initially to avoid institutions (Nakamoto, 2008). This does not mean, however, that governments cannot participate in these blockchain-based mechanisms. Toxopeus & Polzin (2017) have already named cryptocurrencies as a possible financial instrument for public-private collaboration, and governments have already been experimenting with the technology (Koopman, 2018). Moreover, the system can essentially be used by anyone with the proper knowledge and access to the internet; this includes public organizations.

Understanding and monetizing nature's benefits, perhaps the most significant barrier to funding NbS, remains to be solved. In line with Mayor et al. (2021), the findings showed that determining the value of nature is one of the main funding barriers to upscaling NbS. The results do not indicate a real solution but show that carbon sequestration is now often used as a proxy for these values. The MRV systems can gather data on the abundance and height of plants and trees and make this data transparent by storing it on the blockchain. Tracking the growth and protection of vegetation can be used to calculate the amount of carbon a particular plot of project sequesters. This is a widely accepted measure that interests investors (e.g., Interview H). The findings also show that problems can arise when only optimizing for carbon. Interview A mentioned that carbon sequestration is not even in the top 10 most important benefits of NbS, especially for urban NbS. Interview H agrees by saying that nature is not a carbon machine. The benefits that NbS have on human health and wellbeing can be far more essential to us but might be overlooked when those are not optimized for. Some companies in the carbon token market acknowledge this problem and work on other methods for accounting ecosystem services. These companies merely use the carbon market because they know investors are willing to pay for carbon sequestration to neutralize their emissions (e.g., Fieldwork Session H). Some companies, however, only optimize for carbon resulting in the plantation of monocultures without benefitting local communities. Therefore, we must develop widely accepted measures for all NbS benefits to use that as input for the system. Because

in theory, this system *can* also work for capturing and valuing the other benefits of NbS. For that to work, we would need a common ground on what should be measured and how that would translate into (monetary) value.

In this light, it must also be noted that there is a discrepancy between blockchain and Nature-based Solutions regarding scaling. Blockchain is decentralized and, therefore, inherently global (Tapscott & Tapscott, 2016), while NbS represents *local* public goods (Dorst et al., 2019). In principle, this does not influence how the mechanisms for funding NbS work. It should, however, be considered when interpreting the results as most companies now use carbon sequestration as a proxy. Carbon emissions are a global problem, and it does not make a significant difference if a ton of carbon is emitted here or on the other side of the world, as it will all end up in the global biosphere (Hall, 1989). The other benefits of NbS are reaped more locally, such as the benefits concerning biodiversity and human wellbeing. When the mechanisms are built around these other benefits, global investors might not be as willing to invest as they are now.

The discussion around tokenizing and monetizing nature does raise some ethical questions. If we value nature monetarily, how do we ensure that we do not forget its intrinsic value? Nature embodies so much more than is often imagined, let alone captured. The danger is that we underappreciate nature, something that Naumann et al. (2011) already concluded is happening. And why can we only value nature if we place it in our economic system? By doing that, the line between nature's price and its value becomes vague. On the other hand, as Interview C also mentioned, if we do not value nature in our economic system, there will always be people with power that destroy it because they are focused on financial gains. Moreover, could the result be good if these methods bring in the necessary funding for protecting and regenerating nature?

Similarly, the use of blockchain is also criticized for its potential challenges. The inclusiveness paradox related to the knowledge gap about blockchain technology is a social risk that should be considered. Oberhauser (2019) also concluded that implementing blockchain-based smart contracts is not as inclusive as some might suggest. Not all stakeholders have access to the knowledge or technology needed to implement this technology. The danger it can bring is that we go towards a crypto-colonialism in which highly educated Western people decide what is best for communities on the other side of the world (Howson, 2020). The interviewees and participants of the fieldwork sessions unconsciously confirmed this worry by highlighting how difficult it is to understand what they are doing, even for big tech corporates such as Microsoft (Fieldwork Session D). Fieldwork Session E also mentioned that the platform's user-friendliness is one of the main challenges. Therefore, stakeholders should be aware of this challenge, especially those creating such platforms.

Furthermore, we should be aware of the hype around blockchain technology, as it can sometimes take up all the focus. The findings show that blockchain technology can be a helpful *tool* to attract funding for NbS, but it must never be the goal to use the technology. This raises some questions on what the purpose of finance really is. Our financial system has an allocative function that determines where our resources and labor force are deployed. In today's financial markets, however, the focus is more on risk and reward. Even in the market for cryptocurrencies, which is developed to radically change the way we do finance, most investors are still only focused on risk-return ratios. It would be good to see a switch in the mindset of the mainstream investor toward allocating their funds to create *real* value. The benefits of Nature-based Solutions show that this real social, ecological, and economic value can be created. Moreover, if we use the right mechanisms, it can even generate a return on investment along the way.

5.1 Implications

The developed framework has some implications for policymakers and managers in the field. One of the main policy implications is that authorities should stimulate the use of these mechanisms through their regulations. Fieldwork Session E mentioned that one of the main challenges for implementing a blockchain-based funding model was satisfying financial regulations. While it might be challenging to regulate the blockchain-based finance market due to its decentralized characteristics, the potential gains from being able to implement the mechanisms proposed in this research are too significant to ignore. Furthermore, there should be more people within local- and national authorities that have knowledge in this field to close the identified knowledge gap.

From the managerial side, organizations working in blockchain and NbS should consider testing the mechanisms in urban areas. Fieldwork Session E argued that this is possible, but the first example still needs to be shown. This will become much easier if widely accepted measures for capturing NbS benefits are developed, but this is something they can work on. Furthermore, when investing in the carbon market to compensate for a company's emissions, there are a few things to consider. First, buy the tokens from a company that uses the blockchain-based mechanisms explained in the framework. The mechanisms increase efficiency and trustworthiness, thereby minimizing the chances of greenwashing. Secondly, remember that carbon is the most accepted proxy of nature's value that is now available, but it is far from perfect. Check if the project is also considering the other benefits of NbS and is not optimizing for carbon sequestration alone. Thirdly, buying carbon credits is no excuse not to innovate and improve your business to prevent emissions. Compensating for emissions is not beneficial if companies stop trying to move toward a real low-carbon economy.

5.2 Limitations

Like every research, there are some limitations concerning this project's theoretical approach and methodology. Although a triangulation of data sources is used for robustness and validity of the findings (Creswell & Miller, 2000), there are still some weaknesses to the data collection. First, the response rate of the potential interviewees was lower than expected, leading to only six interviews. More interviews would have made the findings more robust. They could lead to more diverse insights, especially since in-depth interviews are the essential data source for this type of methodology (Gioia et al., 2013). Adding some secondary interviews with organizations on the long list attempted to close at least part of this gap.

Additionally, some of the interviews and all the fieldwork sessions were conducted with people that work in the space of using blockchain for funding nature preservation and regeneration projects. This gave valuable insight from within the sector but can also cause a bias in the opinion and knowledge of the interviewees. To counter this, there were interviews with experts in these fields that do not work directly in the sector.

Moreover, one should be aware that both fields are relatively young and still emerging. The mechanisms in the framework should be tested further for more robust results. Theoretically, the mechanisms function in an urban environment (Fieldwork Session E), but there is no practical proof yet. Furthermore, the data collected did focus much on the public funding, although this was also pointed out in the literature as one of the barriers to funding NbS. An interview with someone from the municipality to have their view on the topic would have been helpful. For now, this will be advised as an avenue for future research.

5.3 Future Research

As blockchain and Nature-based Solutions are emerging topics in academia, there are plenty of avenues for future research. Probably the most important one is developing accounting systems to capture multiple benefits of NbS. Mechanism 2 of the framework in this paper can be used as a sound basis, but there should be a consensus on the mechanism's inputs in terms of measurements. Companies like Single Earth are working hard to develop measures for biodiversity and ecosystem services, so it could be interesting to go back to this research project in a few years to see how that goes. Moreover, further research should determine the mechanisms' actual results in collected funding, as this research project is merely focused on how the mechanisms work.

Additionally, it would be helpful to test the framework for urban NbS specifically. In Fieldwork Session E, the researcher asked a question about this to one of the founders of Single Earth. The answer was that

the system would potentially work in an urban environment, but that scale is now still a constraint. There could be possibilities if someone decides to implement this for a whole city at once. Linking to this topic, it would also be an excellent addition to focus more specifically on public funding.

The decentralized character of blockchain technology and the common good nature of NbS would make for exciting findings if linked to the digital commons literature, where Eleanor Ostrom is one of the leading authors. This avenue was pointed out by both Interview F and Document H.

6. Conclusion

Nature-based Solutions offer a wide variety of social, ecological, and economic benefits, but there are funding barriers that hinder their mainstream implementation. This research project aimed to discover how these funding barriers can be overcome by leveraging the power of emerging technologies. Two mechanisms are found that leverage blockchain technology to enable funding for NbS. The first is tokenizing natural assets, which improves the tradability and liquidity of NbS by allowing for fractional investment and ownership. Furthermore, the tokens are used to incentivize landowners and communities for good stewardship of NbS continuously. The second mechanism revolves around monitoring and maintaining NbS projects. AI-driven MRV systems directly upload data from satellite imagery and other monitoring devices on the blockchain. The collaboration of these technologies enables the efficient and transparent monitoring of NbS and provides a feasible proof of impact to investors. These systems can overcome NbS funding barriers by enabling the monitoring and maintenance of such projects and attracting private investors by meeting their risk-return requirements. This research thereby contributes to the call for more private sector engagement in NbS funding (Toxopeus & Polzin, 2017) while also adding to the 'blockchain for good' field (Aysan et al., 2021; Eikmanns, 2018).

As the field is still emerging, the mechanisms proposed in the framework should be tested further for more robust results. Our lack of understanding and disability to monetize the benefits of nature, perhaps the most significant funding barrier to NbS, also remains to be solved. Although carbon is now often used as a proxy, this is not seen as a long-term solution. Further research should develop a widely accepted measure for capturing multiple benefits. This new knowledge can be combined with the framework developed in this research project to upscale the implementation of NbS. The mechanisms are there, and the solutions are promising, so all that rests is to act now and leverage these benefits for a greener, healthier, and happier society.

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Appendix 1: Blockchain Terminology

Source: CompTIA Blockchain Advisory Council (2020)

Blockchain	A mathematical structure for storing digital transactions or data in an immutable, distributed, decentralized digital ledger consisting of blocks that are linked via cryptographic signature that is nearly impossible to fake, hack or disrupt.
Bitcoin	The first and most popular cryptocurrency based on DLT technology developed from a whitepaper written by Satoshi Nakamoto in 2008.
Centralized	A system or process for which there is a singular (i.e., central) source of authority, control and/or truth.
Consensus mechanism	The process used to validate a transaction across a distributed blockchain network designed to achieve Byzantine Fault Tolerance.
DAO	A governance structure without a central authority which rewards good behavior and penalizes bad behavior by a set of pre-defined rules which can only be changes by a vote, which typically requires a stake, adding risk to the process to discourage bad actors, amongst the participants.
Decentralization	A system with no single point where the decision is made. Every node makes a decision for its own behavior and the resulting system behavior is the aggregate response.
Distributed ledger technology (DLT)	The larger class of technology of which blockchain is a subset. A digital system for recording the transaction of assets in which the transactions and their details are recorded in multiple identical copies at the same time with no central data store or administration.
Immutability	The property of being unchangeable. Once a transaction has been added to a block and written to a blockchain, it cannot be changed and therefore is immutable.
Mining	In a public blockchain, the process of verifying a transaction and writing it to the blockchain for which the successful miner is rewarded in the cryptocurrency of the blockchain.
Node	A computer which holds a copy of the blockchain ledger.
Open source	Software products that include permission to use, enhance, reuse, or modify the source code, design documents, or content of the product.
Peer-to-Peer	A direct connection between two participants in a system - can be computer to computer or person to person.
Smart contract	Self-executing computer code deployed on a blockchain to perform a function, often, but not always, the exchange of value between a buyer and a seller.
Token	Cryptographic tokens represent programmable assets or access rights, managed by a smart contract and an underlying distributed ledger. They are accessible only by the person who has the private key for that address and can only be signed using this private key.
Transparency	A primary property of public blockchains whereby any participant in a system or transaction can view the transactions on the blockchain.
Wallet	A digital file that holds coins and tokens held by the owner. The wallet also has a blockchain address to which transactions can be sent.

Appendix 2: Long-list of organizations for interviews

Blockchain for Nature Organizations	Activity	Website
Veritree	Uses blockchain to mitigate risk of double counting trees and to add transparency to project funders. This provides a cloud-based, verifiable procedure for producing carbon credits in the future	https://www.veritree.com/technology
Regen Network	Reverse climate change with digital carbon and regenerate ecosystems	https://www.regen.network
Single Earth	Single Earth is an online platform that enables forests, wetlands, and other natural resources to generate profit without being sold as raw materials … but instead as carbon offsets and biodiversity offsets	https://www.single.earth
Moss.Earth	Offsetting carbon footprint using blockchain technology	https://moss.earth
Toucan Protocol	By improving infrastructure for environmental assets in Web3, we help to solve key market issues: fragmentation, inefficiency, a lack of uniform data, and limited access.	https://toucan.earth
Open Forest Protocol	The Open Forest Protocol (OFP) is changing how forestation (reforestation, afforestation and conservation) projects are monitored, verified and funded with blockchain technology.	https://www.openforestprotocol.org
100,000,000 Mangroves	Goal is to use NFTs to finance the restoration of mangrove forests, aiming to plant a total of 100,000,000 mangroves.	https://opensea.io/collection/100000000mangroves
KlimaDAO	Klima DAO gives Web3 builders and users the opportunity to participate in the carbon market through the KLIMA token. KLIMA tokens are fungible, are backed by *at least 1* Verified Carbon Unit* in the Klima DAO treasury, and holders of KLIMA will have the ability to vote on Klima DAO policy.	https://www.klimadao.finance
GainForest	Gainforest is an example of "crypto-conservation", using smart contracts to incentivize farmers in the Amazon to preserve the rainforest in return for internationally crowdfunded financial rewards.Remote sensing using satellites verifies the preservation of a patch of forest, which then triggers a smart contract using blockchain technology to transfer payment.	https://www.gainforest.app/about-us
Treecollective	TreeCollective is an organization that experiments with monetizing the value of trees.	https://www.treecollective.nl
WildEarth	Wildlife conservation NFTs	https://wildearth.tv
Biodiversity Solutions Australia	Biodiversity Offset Credits	https://biodiversitysolutionsaustralia.com.au
TreeCycle	Tokens to plant eucalyptus trees in Paraguay	https://treecycle.ch/en/
Earth Bank of Codes	Solution that aims to put all genetic codes of the biodiversity of the Amazon rainforest on the blockchain. Pharmaceutical companies and scientists will then be offered to buy access to the genetic information using a cryptocurrency, which is programmed to be directly paid to the communities taking care of the rainforest. It recognises indigenous bio-IP ownership and shifts how value is extracted from nature.	https://www.earthbankofcodes.org
FishCoin	Seafood supply chain transparency platform that uses a blockchain protocol to incentivise users to share data about seafood from point of catch to plate. Fisherman and processors are paid by the downstream consumers, regulators or environmentalists for the additional data they provide for each catch thereby assigning value to catch and environmental data. By including data about fishing behaviour the fisherman are also incentivised to fish sustainably resulting in a virtuous circle of behavioural reinforcement.	https://fishcoin.co
Wildcards	Trade cards of animals, proceeds are transfered to biodiversity projects. Cards are always for sale.	wildcards.world
Ant forest (Alipay)	Earn points by making sustainable choices in life	https://www.unep.org/championsofearth/laureates/2019/ant-forest
Global Mangrove Trust	Our goal is to plant as many trees as possible, as quickly as possible.	https://globalmangrove.org
Wildchain	Adopt wildlife, plant trees, and support real-world conservation efforts – all within a mobile game.	https://wildchain.io
Ekofolio	Invest in forestation projects through tokens	https://www.ekofolio.com/how-it-works/
TreeCycle	Use blockchain-based funding mechansism to plant eucalyptus trees.	https://treecycle.ch
Adaptation Ledger	Adaptation ledger is advancing climate adaptation solutions and mobilizing finance through the integration of emerging technologies, smart standards and a unified metric for vulnerability reduction	https://www.adaptationledger.com
Earth ledger	Earth Ledger is a positive social and environmental impact platform that resolves the 17 SDG's whilst making them profitable. It incentivizes verified users to work together towards the restoration of our Planet.	https://earthledger.one
Other		
Founder Winding Tree	Blockchain expert	
Regenopolis	A 360-solution unlocking eco-projects deal flow for regenerative cities, matching aligned capital, leveragingtechnology & 4IR solutions to regenerate, replenish and sustain our urban and natural environment for the benefitof thriving communities and future generations.	
Blockchain Commission for Sustainable Development	Blockchain Commission for Sustainable Development was established to develop a multi-sectoral framework to support the United Nations system, along with Member States, Intergovernmental Organizations, the private sector and civil society, in utilizing blockchain-based technologies to develop local, national and global solutions for the most pressing issues of our day.	
Nature4Climate	Nature4Climate promotes the critical role that nature plays in restoring balance to our climate.	https://nature4climate.org/about/
Circular Finance Lab	Experience with using blockchain for sustainability purposes.	https://circularfinancelab.nl
Author PWC report	Author PwC report on blockchain for sustainability	
Green digital finance allience	Author of the report on blockchain for biodiversity	https://greendigitalfinancealliance.org/#contact
Internet of Nature	Much knowledge in the field of technology for the good of nature and NbS.	https://www.nadinagalle.com

Appendix 3: Data Overview

INTERVIEWS

Code	Organization	Role	Duration
Interview A	Internet of Nature	Founder	42 min.
Interview B	Open Forest Protocol	Funding Manager	28 min.
Interview C	TreeCollective	Co-Founder	32 min.
Interview D	Winding Tree	Blockchain Expert	35 min.
Interview E	Regen Network	Grants Manager	Email
Interview F	Circular Finance Lab	Founder	2 sessions, total 40 min. (no recording)

SECONDARY DATA

Code	Interviewee	Platform	Interview Link
Interview G	Nature4Climate (founder)	Internet of Nature podcast	Link
Interview H	Single Earth (founders)	Youtube	Link

Code	Document	Organization	Document Link
Document A	Green Fintech Taxonomy and Data Landscaping	GDFA + SGFN	Link
Document B	Fintech for Biodiversity Finance	Green Digital Finance Allience	Link
Document C	Blockchain for Biodiversity Finance	UN Environment Programme | Finance Inititative	Link
Document D	Blockchain: Gateway for sustainability linked bonds	HSBC + Sustainable Digital Finance Allience	Link
Document E	Tokenization of infrastructure: a blockchain-based solution to financing sustainable infrastructure	International Institute for Sustainable Development	Link
Document F	Regen Network White Paper	Regen Network	Link
Document G	Open Forest Protocol Wite Paper	Open Forest Protocol	Link
Document H	GainForest White Paper	GainForest	Link

FIELD WORK

Code	Session	Participants	Platform
Session A	Toucan Office Hours 10-05-2022	Toucan Protocol	Discord
Session B	Toucan Twitter Space 18-05-2022	Toucan Protocol, Solid World DAO	Twitter
Session C	Toucan Office Hours 24-05-2022	Toucan Protocol	Discord
Session D	Toucan Twitter Space 08-06-2022	Toucan Protocol, Regen Network, Open Forest Protocol, Moss Earth	Twitter
Session E	Single Earth 'Ask Me Anything' 16-06-2022	Single Earth's founders	Discord

Appendix 4: Interview guide

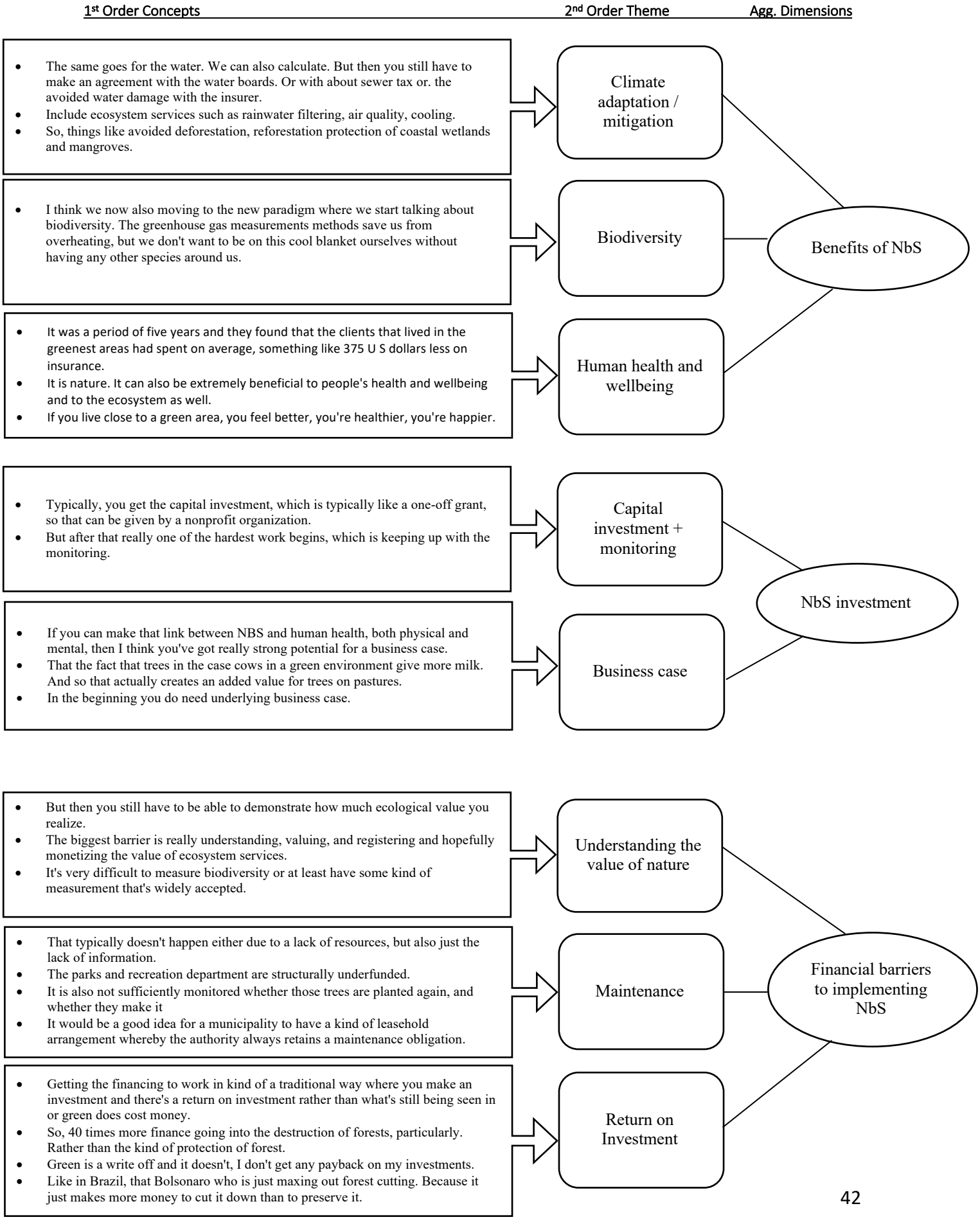
Topics	Questions
Interview category 1	
Nature-based Solutions	• Tell me about your project, how did you get started? • How are you using nature? • What problems do you solve? • What are the benefits of using NbS? • How do you measure the benefits of a project?
Financing NbS	• What does an investment in NbS look like? • Does investing in NbS offer a financial return? • What are the other gains? • How did you obtain funding? • In what ways does technology play a role in financing NbS?
(Financial) barriers to implementing NbS	• Did you encounter barriers when implementing NbS? • Can you tell me more about that? • How about financial barriers? • Are those barriers still there? • How did you overcome these barriers?
Blockchain as a solution for NbS financial barriers	• How are you using blockchain in your project? • What functions of blockchain do you use? • Is blockchain the only way to do this? • Does it help to overcome certain barriers? • Are there challenges you encountered when implementing blockchain? • Would blockchain be beneficial for more purposes regarding NbS?
Interview category 2	
Blockchain for sustainability transitions	• In what ways does blockchain play a role in sustainability transitions? • Do you have specific examples? • How does blockchain help to finance sustainability projects? • How does decentralization play a role in this? • And what about smart contracts? • Can you tell me more about asset tokenization?
Risks and challenges of blockchain	• What are the challenges to implementing today? • What is the near-future prospect for this?

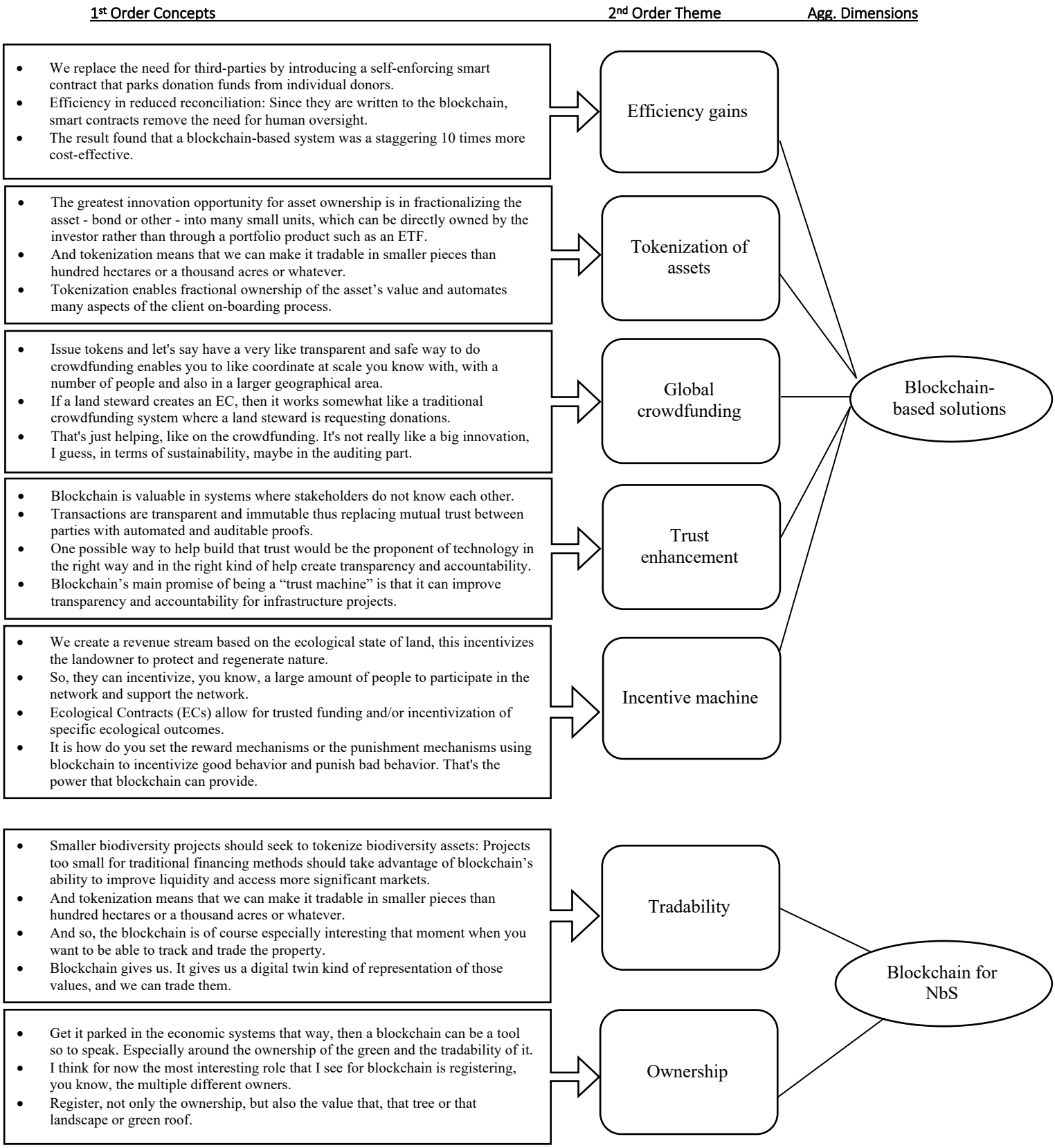
Blockchain as a solution for NbS financial barriers	• I will explain broadly what the financial barriers to NbS are • In what ways do you think blockchain could be used to overcome such challenges? • Do you have any examples of similar cases? • Are there other fields of sustainable development where blockchain is used to overcome financial barriers?

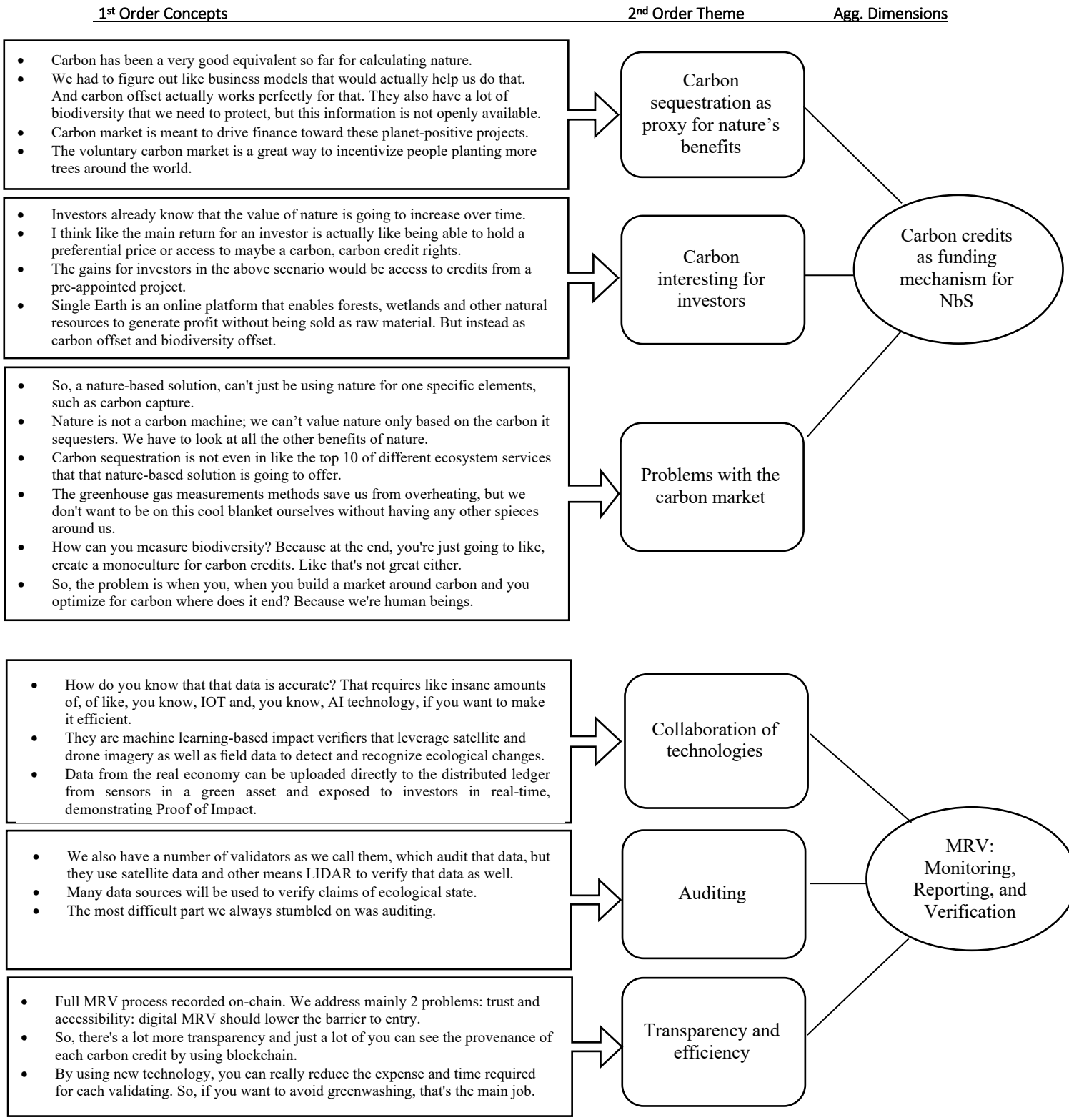
Appendix 5: Codebook

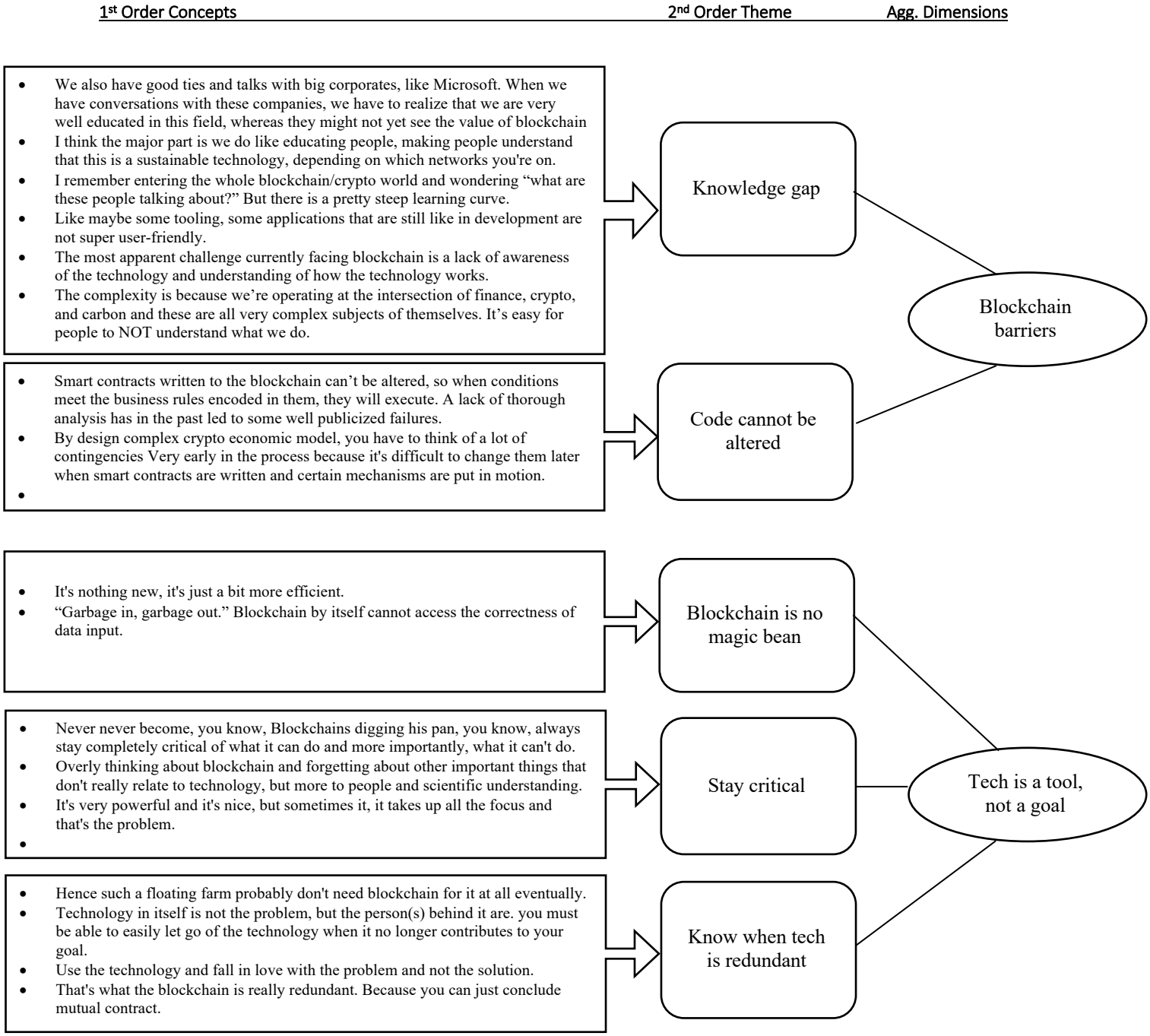
First level code	**Second level code**
Nature-based Solutions	
	NbS investment
	NbS benefits
	NbS barriers
Technology for NbS	
	Blockchain for NbS
	Tech is a tool
	Fintech
	Collaboration of technologies
	MRV
Blockchain	
	Blockchain solutions
	Blockchain downsides
	Blockchain business model
	Blockchain barriers
	Blockchain is no magic bean
Carbon market	
	Carbon credits
	Price carbon credits
	Downside carbon credits

Appendix 6: Data Structure




1st Order Concepts
2nd Order Theme
Agg. Dimensions
We replace the need for third-parties by introducing a self-enforcing smart contract that parks donation funds from individual donors.
Efficiency in reduced reconciliation: Since they are written to the blockchain, smart contracts remove the need for human oversight.
The result found that a blockchain-based system was a staggering 10 times more cost-effective.
Efficiency gains
The greatest innovation opportunity for asset ownership is in fractionalizing the asset - bond or other - into many small units, which can be directly owned by the investor rather than through a portfolio product such as an ETF.
And tokenization means that we can make it tradable in smaller pieces than hundred hectares or a thousand acres or whatever.
Tokenization enables fractional ownership of the asset's value and automates many aspects of the client on-boarding process.
Tokenization of assets
Issue tokens and let's say have a very like transparent and safe way to do crowdfunding enables you to like coordinate at scale you know with, with a number of people and also in a larger geographical area.
If a land steward creates an EC, then it works somewhat like a traditional crowdfunding system where a land steward is requesting donations.
That's just helping, like on the crowdfunding. It's not really like a big innovation, I guess, in terms of sustainability, maybe in the auditing part.
Global crowdfunding
Blockchain is valuable in systems where stakeholders do not know each other.
Transactions are transparent and immutable thus replacing mutual trust between parties with automated and auditable proofs.
One possible way to help build that trust would be the proponent of technology in the right way and in the right kind of help create transparency and accountability.
Blockchain's main promise of being a "trust machine" is that it can improve transparency and accountability for infrastructure projects.
Trust enhancement
We create a revenue stream based on the ecological state of land, this incentivizes the landowner to protect and regenerate nature.
So, they can incentivize, you know, a large amount of people to participate in the network and support the network.
Ecological Contracts (ECs) allow for trusted funding and/or incentivization of specific ecological outcomes.
It is how do you set the reward mechanisms or the punishment mechanisms using blockchain to incentivize good behavior and punish bad behavior. That's the power that blockchain can provide.
Incentive machine
Blockchain-based solutions
Smaller biodiversity projects should seek to tokenize biodiversity assets: Projects too small for traditional financing methods should take advantage of blockchain's ability to improve liquidity and access more significant markets.
And tokenization means that we can make it tradable in smaller pieces than hundred hectares or a thousand acres or whatever.
And so, the blockchain is of course especially interesting that moment when you want to be able to track and trade the property.
Blockchain gives us. It gives us a digital twin kind of representation of those values, and we can trade them.
Tradability
Get it parked in the economic systems that way, then a blockchain can be a tool so to speak. Especially around the ownership of the green and the tradability of it.
I think for now the most interesting role that I see for blockchain is registering, you know, the multiple different owners.
Register, not only the ownership, but also the value that, that tree or that landscape or green roof.
Ownership
Blockchain for NbS


1st Order Concepts
2nd Order Theme
Agg. Dimensions
Carbon has been a very good equivalent so far for calculating nature.
We had to figure out like business models that would actually help us do that. And carbon offset actually works perfectly for that. They also have a lot of biodiversity that we need to protect, but this information is not openly available.
Carbon market is meant to drive finance toward these planet-positive projects.
The voluntary carbon market is a great way to incentivize people planting more trees around the world.
Carbon sequestration as proxy for nature's benefits
Investors already know that the value of nature is going to increase over time.
I think like the main return for an investor is actually like being able to hold a preferential price or access to maybe a carbon, carbon credit rights.
The gains for investors in the above scenario would be access to credits from a pre-appointed project.
Single Earth is an online platform that enables forests, wetlands and other natural resources to generate profit without being sold as raw material. But instead as carbon offset and biodiversity offset.
Carbon interesting for investors
Carbon credits as funding mechanism for NbS
So, a nature-based solution, can't just be using nature for one specific elements, such as carbon capture.
Nature is not a carbon machine; we can't value nature only based on the carbon it sequesters. We have to look at all the other benefits of nature.
Carbon sequestration is not even in like the top 10 of different ecosystem services that that nature-based solution is going to offer.
The greenhouse gas measurements methods save us from overheating, but we don't want to be on this cool blanket ourselves without having any other spieces around us.
How can you measure biodiversity? Because at the end, you're just going to like, create a monoculture for carbon credits. Like that's not great either.
So, the problem is when you, when you build a market around carbon and you optimize for carbon where does it end? Because we're human beings.
Problems with the carbon market
How do you know that that data is accurate? That requires like insane amounts of, of like, you know, IOT and, you know, AI technology, if you want to make it efficient.
They are machine learning-based impact verifiers that leverage satellite and drone imagery as well as field data to detect and recognize ecological changes.
Data from the real economy can be uploaded directly to the distributed ledger from sensors in a green asset and exposed to investors in real-time, demonstrating Proof of Impact.
Collaboration of technologies
We also have a number of validators as we call them, which audit that data, but they use satellite data and other means LIDAR to verify that data as well.
Many data sources will be used to verify claims of ecological state.
The most difficult part we always stumbled on was auditing.
Auditing
MRV: Monitoring, Reporting, and Verification
Full MRV process recorded on-chain. We address mainly 2 problems: trust and accessibility: digital MRV should lower the barrier to entry.
So, there's a lot more transparency and just a lot of you can see the provenance of each carbon credit by using blockchain.
By using new technology, you can really reduce the expense and time required for each validating. So, if you want to avoid greenwashing, that's the main job.
Transparency and efficiency


1st Order Concepts
2nd Order Theme
Agg. Dimensions
We also have good ties and talks with big corporates, like Microsoft. When we have conversations with these companies, we have to realize that we are very well educated in this field, whereas they might not yet see the value of blockchain
I think the major part is we do like educating people, making people understand that this is a sustainable technology, depending on which networks you're on.
I remember entering the whole blockchain/crypto world and wondering "what are these people talking about?" But there is a pretty steep learning curve.
Like maybe some tooling, some applications that are still like in development are not super user-friendly.
The most apparent challenge currently facing blockchain is a lack of awareness of the technology and understanding of how the technology works.
The complexity is because we're operating at the intersection of finance, crypto, and carbon and these are all very complex subjects of themselves. It's easy for people to NOT understand what we do.
Knowledge gap
Smart contracts written to the blockchain can't be altered, so when conditions meet the business rules encoded in them, they will execute. A lack of thorough analysis has in the past led to some well publicized failures.
By design complex crypto economic model, you have to think of a lot of contingencies Very early in the process because it's difficult to change them later when smart contracts are written and certain mechanisms are put in motion.
Code cannot be altered
Blockchain barriers
It's nothing new, it's just a bit more efficient.
"Garbage in, garbage out." Blockchain by itself cannot access the correctness of data input.
Blockchain is no magic bean
Never never become, you know, Blockchains digging his pan, you know, always stay completely critical of what it can do and more importantly, what it can't do.
Overly thinking about blockchain and forgetting about other important things that don't really relate to technology, but more to people and scientific understanding.
It's very powerful and it's nice, but sometimes it, it takes up all the focus and that's the problem.
Stay critical
Hence such a floating farm probably don't need blockchain for it at all eventually.
Technology in itself is not the problem, but the person(s) behind it are. you must be able to easily let go of the technology when it no longer contributes to your goal.
Use the technology and fall in love with the problem and not the solution.
That's what the blockchain is really redundant. Because you can just conclude mutual contract.
Know when tech is redundant
Tech is a tool, not a goal