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Review

Linking Climate Change Adaptation and Mitigation: A Review with Evidence from the Land-Use Sectors

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Abstract: There is extensive scientific evidence that both adaptation and mitigation are essential to address the problem of climate change. However, there is still limited knowledge about the possibilities for exploiting the interrelationships between these measures in the design and implementation of climate change activities. In this paper, first the adaptation–mitigation dichotomy and definitions of adaptation and mitigation are discussed. This is followed by a comprehensive scrutiny of the perceptual overlaps and distinctions between adaptation and mitigation, which include a meta-analysis of synergies and trade-offs between adaptation and mitigation in the agriculture and forestry sectors. The analysis shows that activities greatly depend on their context, design and implementation, so actions have to be tailored to the specific conditions, as few, if any, outcomes are universal. The analysis also indicates that the forestry sector delivers more synergies and has more trade-offs when compared to agriculture, which could be because of the fact that forest areas contain significantly more carbon, but at the same time they also compete with alternative land-uses. The article closes by going through a list of research gaps related to the linking of adaptation and mitigation and by providing implications for climate change policy.

Keywords: climate change; adaptation; mitigation; forestry; agriculture; land use; linking; integration; interaction; inter-relationship

1. Introduction

The overall aim of this review article is to contribute to the empirical knowledge base on the opportunities and challenges of enhancing the linkages between adaptation and mitigation, with a special emphasis on the land-use sectors (i.e., agriculture and forestry). The findings should assist in funding being invested more effectively, as well as lead institutions and project developers to consider linking adaptation and mitigation in climate-related projects and activities as a trajectory to enhance overall outcomes in combating climate change. Today, there is no longer any doubt about the need for both adaptation and mitigation if climate change is to be abated effectively, and there is agreement that actions are necessary at all spatial scales and that they should address short-term as well as long-term issues. However, the climate debate has in recent decades been focused on a global mitigation agreement with long-term perspectives, with less attention being given to adaptation. One could ask why climate projects are still one-sided regarding adaptation or mitigation when the doubts about the need for both have gone? The intuitive thought is that it must be feasible and better to make 'climate' projects that address both objectives. At least in the cases where interlinkages between adaptation and mitigation exist, because the divide can often be explained by the spatial and temporal differences and sectoral circumstances between the two objectives. However, in the land-use sectors, for instance, which is the main field of research in this article, this sharp split and narrow-minded focus appears at first sight remarkable.

Others have made the same observation; some scholars have referred to it as 'the false dichotomy' framed by scientists and policy-makers [1–5]. Several studies have made reflections on a number of

different types of linkage between adaptation and mitigation (e.g., References [6–8]. However, the main way of implementing this linkage, 10 to 20 years ago, was to assess the level of possible substitution between the two objectives, as the need and scope for adaptation was solely an aftermath of our (in)ability to mitigate climate change—a 'cause and effect' interaction [9]. The idea, at that time, was to remove the artificial barrier between mitigation and adaptation in order to get a balance between them in global and national strategies [10]. Nevertheless, the policy attention towards adaptation started to increase, primarily triggered by the fact that past emissions started to show impacts, particularly in vulnerable developing countries, and because the international climate negotiations about climate change mitigation had made almost no progress [11]. These two circumstances might have been the main factors that moved adaptation to the front next to mitigation, but maybe more interestingly, some scholars turned their research towards the interplay between mitigation and adaptation.

These scholars investigated the possibilities of complementarities or even synergies and whether their interplay was complicated by trade-offs (e.g., References [6,9,11–16]) and not just adaptation and mitigation as separate measures. These studies, not surprisingly, revealed a complexity of positive, neutral and negative effects, but had the interplay been demonstrated, it could not be neglected. Lately, this interplay has expanded to include development issues, as all three have substantial overlaps, and to increase effectiveness and efficiency, there is a growing quest for creating synergies and suppressing trade-offs between these three objectives [4,8,17]. For instance, "it has been suggested that linking adaptation to mitigation in some cases may contribute to repairing the discursive rift between climate policy and sustainable development" (Venema and Rehman 2007 in [16] p. 757), for which reason this trinity, if successful, has been referred to as 'triple wins', multiple 'wins', or simply as holistic in approach [8,17,18]. It has even been commented "that the separate treatment of mitigation and adaptation in both science and policy has hindered progress against the fundamental sustainable development challenges of climate change" [16] (p. 754). On the other hand, scholars are also noting that linking adaptation and mitigation into a single portfolio is no panacea and should not be implemented with force, as it can lead to a ballooning of policies and projects that is unmanageable and cost-ineffective [9,11,13,19,20]. However, in some areas, like the land-use sector in the developing world, it is obvious that it should be considered as a central part of the overall guidelines [5,18].

Thus, the suggestion is to move beyond a single-impact focus and cost-benefit analysis if studies are to provide better understanding of the possibilities of linking adaptation and mitigation and to avoid trade-offs in projects and policies [18,21]. This is because little is known about the enabling conditions for design and implementation to move from the current dichotomized approach to the synergy approach [5]. This article addresses this research gap by investigating the possibility of enhancing the empirical understanding of linkages between adaptation and mitigation in the land-use sectors. A stronger evidence base in this research field can ensure that funding is invested effectively, for instance, in 'no-regret' options that deliver multiple benefits, whereas the lack of an evidence base of practices to achieve this may significantly limit the capacity of donors to identify, monitor and evaluate investments [18,22]. The outcome is believed to be a part of the process to overcome sustained conceptual divides between adaptation and mitigation, and it is believed that this will lead to a growing interest in mitigation in the countries that are focused on their adaptation needs, and likewise increase awareness of the benefits that adaptation can bring to mitigation measures.

Section 2 scrutinizes the historical background of climate change adaptation and mitigation, and Section 3 discusses the definitions of adaptation and mitigation and the perceptual overlaps/distinctions between them. Section 4 contains an elaboration of the potential for linking adaptation and mitigation in agriculture and forestry, as a case. Finally, Section 5 identifies research gaps and Section 6 identifies the implications for policy. The approach of the meta-analysis was the following: The point of departure was Klein et al. 2007 [6], and later Kane and Shogren 2000 [12], Dang et al. 2003 [9], Klein et al. 2005 [13], Burton et al. 2007 [14] and Swart and Raes 2007 [11]. This was followed by a thorough search for related articles by means of various search engines and snowball sampling. To be included, the main research focus of the article (or report) had to be the

linking of climate change adaptation and mitigation. Year of publication had no influence in the search for relevant articles, but later, it was of great importance in the review of the history (Section 2). The geographical focus of a particular article had no influence. Nevertheless, the majority of the included material is focusing on the tropics, especially the articles included in Section 4. NVivo was utilized to organize and categorize the material.

2. Background: The Adaptation-Mitigation Dichotomy

The question of dealing with climate change is divided into adaptation, which has been defined as "adjustment in natural or human systems in response to actual or expected climatic stimuli or their effects, which moderates harm or exploits beneficial opportunities", and mitigation, which is any "anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gasses" [23]. The distinction is also reflected in the working group structure of the IPCC (WGII: Adaptation and WGIII: Mitigation), funding mechanisms (e.g., CDM, JI and NAMA are mitigation, and Adaptation Fund and NAPA are adaptation) and in the scientific sphere, where scholars mostly concentrate on one of these objectives and disregard the other. However, the overall objective of both approaches is the same, to deal with climate change. However, this sharp dichotomy makes less sense [9], as it is widely recognized that adaptation and mitigation are interlinked and that both are necessary for combating climate change [24]. To uncover the explanation for this dichotomy, we have to dig into the history of the climate negotiations.

In the 1980s, scientists placed climate change on the global environmental agenda, which also affected the policy agenda. Thus, in 1988 the UN General Assembly formally took up climate change for the first time, and in 1992 the UN enacted the UNFCCC in order to facilitate coordination of an international response to anthropogenic climate change [14]. At that time, science understood climate change to be an environmental pollution problem in the same manner as two other major atmospheric problems: acid rain and the ozone layer depletion, which were both critical transboundary and systemic environmental challenges that had both been handled successfully through international cooperation. Therefore, to solve climate change, a policy framework approach was applied in which neutral scientific assessments were conducted (by the IPCC), which were communicated to policy-makers (by the UNFCCC), and were to be transformed subsequently into international emissions targets through a global environmental regime [14,16]. At this stage, it was believed that mitigation, i.e., reducing emissions and increasing sinks, was sufficient [10], and politicians and scholars who only mentioned adaptation were frowned on, as this was viewed as giving up prematurely [25,26]. Proponents of adaptive strategies were thus ignored as 'defeatists', 'fatalistic' and linked to 'do nothing strategies' [3]. Some of the latter were referred to as 'adaptationists', i.e., those who saw no need to take any action, as they simply trusted in autonomous adaptation and expect future generations to have more income and more sophisticated technologies to enable them to cope with future climate change [9,27].

Thus, adaptation was treated as a taboo subject, as it was perceived either as representing a failure of mitigation or as a way to weaken mitigation efforts [28]. For instance, Al Gore (Vice President of the United States 1993–2001) forcefully declared his opposition to adaptation in 1992 by stating: "believing that we can adapt to just about anything is ultimately a kind of laziness, an arrogant faith in our ability to react in time to save our skin" [28] (p. 597). Additionally, adaptation was also seen as a disreputable and an unfair plan B, as politicians and scholars already knew back then that climate change would hit developing countries harder. They were held to be irresponsible for causing the problem and as having lower adaptive capacity, whereas the "responsible" developed countries had abundant capacity to resist the impacts [29] (p. 1117). As a consequence, consensus was based on the "polluter pays principle"—or the 'if you broke it, you fix it' approach [30]. The "polluter pays" approach, which is a fundamental part of climate finance politics, has created a new global relationship between developed and developing countries [31]. Whereas before, in some cases, we were talking about charity and aid, the word now being used in the climate talks was "compensation". This has been a game-changer, as compensation is less humiliating because it is something you have a right to.

However, the notable differences between adaptation and mitigation, especially spatial and temporal scales [32,33], also played a major role in creating this dichotomy and the focus on mitigation internationally. Mitigation was highly regarded as a global issue to be tackled internationally, whilst adaptation was a local concern to be dealt with by national or local policy-makers. Temporally mitigation had to be dealt with right now, whereas adaptation was considered a problem for future generations, if it were to occur at all [11]. This can also be seen in the ultimate objective of the UNFCCC, which is to achieve "stabilization of greenhouse gas concentrations in the atmosphere at a level that would prevent dangerous anthropogenic interference with the climate system [and] within a time frame sufficient to allow ecosystems to adapt naturally" [34] (Art. 2). It was also reflected in the IPCC's third assessment report, which stated that "climatic changes today still are relatively small, thus there is little need for adaptation, although there is considerable need for mitigation to avoid more severe future damages".

Pielke [35] comments that the UNFCCC's definition of adaptation (also adopted partly by IPCC WGIII) has created a bias against adaptation, as adaptation in this definition only has costs and is viewed as something that should only be employed when mitigation fails to prevent the impacts (more on definitions in Section 3). One consequence of the UNFCCC's narrow definition of climate change is that it necessarily subjugated all climate policy to energy policy, as it is widely considered to be the only policy tool that can control the global production of goods, which fashioned the mitigation focus [35]. Nonetheless, a framework for adaptation actions had already been set up within the legal frameworks of the UNFCCC from 1992 (Article 4), which, for instance, recognizes the need for adaptation as well as mitigation by stating that "All Parties ... shall ... formulate, implement, publish and regularly update national and ... regional programmes containing measures to mitigate climate change ... and measures to facilitate adequate adaptation to climate change" [34] (Art. 4.1b); and further, that countries shall "Cooperate in preparing for adaptation to the impacts of climate change" (Art. 4.1e), and that developed countries shall assist developing countries to meet the costs of adaptation (Art. 4.4).

Retrospectively, viewing climate change as an environmental pollution issue that could be solved by international agreements resulted in a mitigation–adaptation dichotomy with a narrow focus on mitigation (e.g., References [3,9,11,14,17]. From a precautionary principle point of view, which often is an important principle in environmental politics, it was sound for negotiators in the beginning to support mitigation as a primary instrument against the challenge ahead. The precautionary principle has been interpreted by many, but the basic idea is to avoid actions where the consequences are uncertain [36]. However, the statements regarding causes and effects in the IPCC reports became stronger, and already in 2001, the IPCC [23] underscored that significant impacts of climate change were unavoidable, which justified including adaptation strategies before climate change impacts materialized if the precautionary principle was to be followed [9]. Smith [37] (p. 252) notes that, "if climate change is inevitable, adaptation to its effects is also inevitable", and others comment that the need for adaptation to climate variability and extreme events in some regions is contemporary and not just a matter of proactive measures [38]. A few years later, scholars emphasized that collective adaptation efforts are likely to be needed in most countries [10]. Consequently, attention to the necessity for adaptation should have increased gradually since the Earth Summit (Rio 1992) and COP1 (Berlin 1995), as the following negotiations (mainly the COPs) produced very limited results with regard to reducing emissions significantly, and impacts of climate change started to occur [39].

The attention given to adaptation as an alternative or complementary response strategy to mitigation has increased since the turn of the millennium [3,16,17,38,39]. Adaptation was translated into policy in 2001 (COP7 in Marrakech) through the creation of three funds focusing on it, including the 2% CDM-levy financed Adaptation Fund (The others were the Least Developed Countries Fund and the Special Climate Change Fund, both under the auspices of the Global Environmental Facility) [10]. Again in 2007 (COP13 in Bali), adaptation was elevated to be a 'building block' alongside mitigation, technological cooperation and finance [16]. During the same period, the production of knowledge

on climate change was reshaped from being framed as an environmental problem, with studies not considering adaptation at all [25] towards a human-influenced development issue, and it has shifted from being a mono-disciplinary approach with an emphasis on the natural sciences "towards [being] a transdisciplinary research strategy with stronger focus on co-production of scientific knowledge between natural and social scientists, policy makers, and society to support political decisions in the context of sustainable development" [3] (p. 231). Nevertheless, only a decade ago the primary focus was still on mitigation, for instance, in the national communications, in which, although adaptation and mitigation were mentioned simultaneously, adaptation was frequently not treated as intensively as mitigation, and government officials and analysts perceived mitigation and adaptation as discrete or pure substitutes of one another [9]. Further, scholars [9] (S83) asked why it had "taken such a long time for researchers and policy makers alike to pay adequate attention to adaptation?" and why almost all policy-makers and negotiators had "considered mitigation and adaptation as unrelated policy alternatives or even opposing the latter?". In 2007, Burton and colleagues wrote that the underestimation of adaptation largely persists, and when adaptation is considered, it is, unfortunately, "often merely to lament the lack of adaptive capacity in the poorest and most vulnerable communities and countries", so that "research into the processes and techniques of adaptation still continue to be neglected" [14] (p. 373). A few years later, Ayers and Huq [16] (p. 756) commented that there remains some degree of institutional bias toward mitigation over adaptation despite progress, which is "limiting the scope of action on adaptation to contribute to sustainable development".

Moser [17] claims that adaptation follows the history of sometimes disharmonious or at least one-sided discussions of climate change and that it lags far behind mitigation. She adds that "There is considerable communication yet to be done to challenge and replace old attitudes and perspectives which view mitigation and adaptation as alternatives, rather than as complementary and necessary approaches to managing climate risks" [17] (p. 172). She states that resistance to tackling adaptation is often based on the belief that talking about adaptation is a form of capitulation [17]. Furthermore, discussions about the spatial and temporal scale differences between adaptation and mitigation still take place, but they are less pronounced, as the overlaps are greater than hitherto assumed (see Section 4.1 for discussion of overlaps). Nevertheless, the mitigation strategy is mainly a top-down approach that is considered easier to implement in comparison to adaptive strategies, which largely involve a bottom-up approach. In addition, the latter is associated with complicated policy strategies such as participatory approaches, multi-level governance or multi-stakeholder platforms [3], which can be instrumental in the continued favoring of mitigation. However, this bottom-up/top-down difference might be a misperception, as mitigation in some cases has to come from the ground up [40].

In spite of the increased political attention being given to adaptation, the disharmony between adaptation and mitigation is still apparent in terms of funding, with a dominant role for mitigation. Back in 2007, Pielke and colleagues called adaptation mitigation's "poor cousin" in the climate policy arena, as historically it had been treated as a marginal policy option by climate change scientists and decision-makers [28] (p. 598); a label that sticks. In 2010/11, as much as 96% of global climate finance (350 billion USD) was allocated to mitigation activities alone [41], and in 2013 adaptation was still being deprioritized financially, though the figures indicated some improvement; 80% of funding going to mitigation (of which some 15% for REDD), 15% to adaptation, and 5% of funds being distributed to projects with multiple foci [21]. In 2015/16, the picture was more or less unchanged: Adaptation finance was at 16% of public climate finance flows [42]. With regard to this and to the overall topic of this article, it is naturally very interesting to notice that in 2013 only 3% of climate financing was used for activities with joint mitigation and adaptation objectives, and only a small improvement has been observed in recent years: The 2015-16 average spent on dual benefits was 4% of climate financing [42].

3. Defining Adaptation and Mitigation

In order to analyze the link between adaptation and mitigation, it is necessary to clarify the definitions and substances of mitigation and adaptation. They both represent responses to climate

change and are driven by the same problems, however, they have fundamentally dissimilar approaches and essential differences (e.g., References [6,11,19,20,25,38], which will be elaborated further after discussing the definitions.

People, including researchers, become confused over the meanings of adaptation and mitigation, and even replace them. The confusion arises because to mitigate means to abate, moderate or alleviate some expected impacts—at least in engineering and insurance, or in the field of environmental hazards. However, in 'climate change science' it is considered to be a response in the form of "reducing or stabilizing GHG emissions or levels, in order to mitigate changes in climate" [38] (p. 224–225). In the climate change context, mitigation focuses on the causes of climate change [18], and scholars have referred to mitigation as indirect damage prevention [43], actions taken to reduce the extent of climate change [22], or actions to avoid the unmanageable [44]. The most commonly cited and applied definition of mitigation runs: "anthropogenic intervention to reduce the sources or enhance the sinks of greenhouse gases", which comes from the IPCC's third assessment report [23], and was also used in the fifth assessment report [24]. Mitigation activities can broadly be grouped into five main areas: Efficient use of energy (i.e., reducing system waste); use of renewable energies (such as solar, biofuels, wind, and ocean thermal exchange); carbon sequestration through enhanced sinks (e.g., reforestation and afforestation); reduced sources of emissions through land use management; and macro-engineered carbon capture and storage [22].

To adapt, on the other hand, means to modify or alter something to make it more fit for a purpose, while adaptation, a term often used in ecology and social science, "refers to both the process of adapting and the condition of being adapted" [45] (p. 203). One climate-related definition of adaptation is adjustments "in ecological-social-economic systems in response to actual or expected climatic stimuli, their effects or impacts" [38] (p. 225), but it comes in both narrower and broader versions. This requires its users to specify which version is being used with regard to who (i.e., people, social and economic sectors, and activities, managed or unmanaged natural or ecological systems, or practices, processes or structures of systems), what (i.e., climate change, climate variability and/or extreme events) and how adaptation occurs [38]. Adaptation is used to describe all activities aimed at preparing for or dealing with the consequences of climate change [46], for instance, building dams in flood-prone areas or cutting firebreaks in fire-prone areas. Scholars have referred to adaptation as direct damage prevention [43] and as managing the unavoidable [44], as well as actions taken to ameliorate impacts [22] or actions needed to avoid adverse impacts [5]. Various types of adaptation can be distinguished with regard to timing (anticipatory/proactive/ex-post, spontaneous/concurrent/during, or responsive/reactive/ex-ante), implementers (private and public), awareness (autonomous or planned), intention (intended or unintended), type (technological, behavioral, economic, legal, or institutional) [4,15,38], or level (incremental, systematic, or transformational) [47]. The most frequently applied definitions are those of the IPCC and UNFCCC, which respectively are that adaptation is "The process of adjustment to actual or expected climate and its effects. In human systems, adaptation seeks to moderate or avoid harm or exploit beneficial opportunities. In some natural systems, human intervention may facilitate adjustment to expected climate and its effects" [48] (p. 118), and "Adaptation refers to adjustments in ecological, social, or economic systems in response to actual or expected climatic stimuli and their effects or impacts. It refers to changes in processes, practices, and structures to moderate potential damages or to benefit from opportunities associated with climate change" [49] (p. 1).

However, there is a variety of definitions of adaptation [9,50], and discussions concerning meaning and interpretation have been going on since the early 1990s. The IPCC, for instance, states in its fifth assessment report that they have adjusted the definition compared to earlier IPCC reports to reflect progress in science [48]. The main disagreement in the discussion of adaptation is rooted in how wide a definition to apply, which is not solely a trivial academic debate, as the definition will profoundly influence the available finances and the feasibility of implementation. The main criticism that has been pointed at institutions (i.a. the UNFCCC) that use adaptation in the narrowest sense,

is that by only referring to actions taken in response to climate change resulting from anthropogenic GHG emissions, they thereby exclude the many societies that are already maladapted to current climate conditions [13,35]. However, this narrow interpretation of climate change is widely accepted, resulting, for instance, in estimates where adaptation actions only represent a cost of human-caused climate change that would be avoided by emissions reduction, thus placing greater emphasis on mitigation, as seen in the past. In contrast to these institutions, the IPCC, like many decision-makers and researchers, does interpret adaptation as "a much broader range of actions that make societies more robust to changes, including, but not limited to, those caused by climate change" [28] (p. 598). The issue is that the UNFCCC's restricted definition of climate change only focuses on changes in climate that result from human activity (directly or indirectly), which makes sense theoretically, but is very difficult to handle in practice and in the real world of politics and policy [35]. Furthermore, this line of thinking will meet little understanding among "those experiencing devastating losses from climate impacts [human or naturally induced] in developing countries" [28] (p. 598).

A decade before Pielke [28,35], scholars were already suggesting that adaptation and vulnerability should be addressed for climate variability and not solely to long-term climate change [51], and that actions should address current problems of sustainable development in the light of variable and uncertain environments [52]. This points backwards to the 'no-regret' term, or measures worth taking, no matter what [53]. Furthermore, it was acknowledged that in general higher capacity could prevent ecosystems and societies from dangerous impacts until the limits of adaptation were reached [6]. Hence, development was recognized as having a significant amount of overlap with adaptation (and vice versa), as reducing vulnerability and increasing adaptive capacity benefits both agendas [54]. This advance represented a significant change in perception in handling climate change impacts, because it was no longer merely the physical exposure to some environmental catastrophe that resulted in environmental vulnerability, but something that was deeply linked with the political, economic, and social contexts in which people lived [16]. This was why "effective adaptation to climate change should include core development concerns associated with vulnerability including but not limited to those directly caused by climate change" [16] (p. 756).

Thus, climate change has gradually been accepted as a development issue [55,56] and, during the last decades, the notion of adaptation has evolved in the direction of making societies more robust and flexible in general, which will facilitate the robustness to climate change and variability, but also to socio-economic changes, many of which are more rapid than global warming [25]. Lately, "there is general acceptance that adaptation involves long-term adjustments within a system [. . .] to better manage external stress" [50] (p. 111), and the overlap with development becomes very natural, as the two have many cross-cutting issues that would contribute to both objectives, for instance, poverty reduction and food security [31]. This involvement with development has made the goals of adaptation less clear-cut, as the actions consist of a wide palette of arrangements, for example, agricultural and land tenure policies, infrastructure, irrigation systems, and livelihood diversification programs [16].

4. The Linking of Adaptation and Mitigation

In this article, it is mainly the word 'linking' that is utilized as the key term, by which is meant to 'join' or 'couple'. In this case, it is the linking of adaptation and mitigation, thus not treating them by default as separate measures, but as measures that potentially have complementarities and synergies. The term 'linking' has been used in a similar way by others [2,12,16,20,57–59]. However, a wide range of terms have been applied by the climate change research community, development organizations, policy-makers, NGOs, and practitioners to cover the same or similar topics. Some use 'integration' [10,11,16,19,27,60–62], others 'interaction' [46,63,64], and others 'inter-relationships' [6,65,66]. In the literature referred above, the terms are used inconsistently to cover what here is referred to as linking, and any discussions related to different meanings of them have not been located, and it has not been possible to determine the reasons for different scholars' selection of the term. The most significant difference in the literature relates to definitions of adaptation, but this is not

mirrored in the term used. Nevertheless, some use 'synergies' deliberately [8,9,15,21,67,68], which only covers one type of linking, but not the topic as a whole. In the next section, it will highlighted in which areas adaptation and mitigation are assumed to be distinct or to overlap respectively in order to provide an understanding of the potential challenges and/or opportunities involved in linking them.

4.1. Perceptual Overlaps and Distinctions between Adaptation and Mitigation

Similarities and differences between adaptation and mitigation have been widely discussed in recent decades, especially in the literature advocating or opposing their integration. The main distinctions have been targeted at spatial, temporal and sectoral issues, but scholars' opinions differ when discussing these. However, the gap seems to have decreased, mainly because limited mitigation action has occurred, which has led to calls with increased emphasis on adaptation. In the past, the perception was that commonalities were minor, for instance, that jurisdictions were different [9,10,25]. Yet, other scholars have emphasized that the gap is smaller than perceived [3,17,28,35,69]. It must be emphasized that the author does not deny the conceptual differences between the adaptation and mitigation, but the author agrees with the group of scholars that recommend a 'less sharp, less categorical rendering of them' [70] (p. 200). The dominant focuses of the two strategies found in the literature are shown in Supplementary 1 [3,4,6,8–11,15–17,19–21,25,27,28,31,33,35,46,69,71–74], together with some exceptions. To provide a better overview it is divided into different issues, but this breakdown has several overlaps.

First, the sharp and simple spatial division that adaptation is local and mitigation is global (Supplementary 1) is less pronounced in the present discussion, as this notion has been challenged. For instance, Swart and Raes [11] and Moser [17] mention examples where adaptation actions can have global consequences (e.g., more resistant crops that are grown globally) and mitigation actions that will have local consequences (e.g., less local air pollution by closing coal-fired power plants, or the effect of biofuels on local food security). Furthermore, mitigation has started to be an important local issue with regards to implementation and cooperation, as individuals, communities, cities, states, and companies take action without any direct payments or benefits [11], but simply out of moral or altruistic reasons. However, some might do this for economic incentives too, as altruistic behavior is a part of their business model (some of these entities might refer to mitigation initiatives, but without limited actions, which has been referred to as 'green-washing' [75]), while others simply see opportunities in the 'green economy' that are developing, and others see it as a 'no-regret' action, as with energy-efficient solutions [75]).

Nevertheless, even if emission-reduction activities have to take place locally [17], the effectiveness of climate change is dependent on the support at the international level and on the participation of all countries [3,72]. Besides, there has been a shift away from the notion that adaptation is for developing countries and mitigation for developed countries, which has been generated by the increasing emissions in developing countries. Moreover, attention to adaptation has increased in the developed world, which is partly a consequence of the significant damage being caused by extreme weather events worldwide. Nevertheless, on the administrative scale the existing constituencies of adaptation and mitigation only marginally overlap [69], as mainstreaming into the different agencies at large has failed, and relatively few public or corporate decision-makers have direct responsibility for both adaptation and mitigation. For example, adaptation is handled by some ministries (like agriculture, forestry, building and infrastructure), while mitigation is located in others (especially energy, trade and finance) [6,25].

Secondly, there is a general attitude regarding the temporal scale of adaptation and mitigation that scholars largely agree on (Supplementary 1). Adaptation (benefits, costs and implementation) is immediate and near-term due to reducing vulnerability to current climate and climate variability, whereas mitigation benefits will affect later generations, although implementation and costs relate to the present. Thus, for mitigation there is a delay between incurring the costs and realizing the benefits, whereas adaptation provides benefits immediately (This difference creates some difficulties in

producing economic assessment of the cost and benefits of the two approaches, especially the impact of using discount rates.). However, this perception has been challenged, for instance, by Moser [17] (p. 169), who states that "reality is far more complex and demands a long-term, life-cycle, and systems perspective to appreciate that in most instances, adaptation and mitigation—regardless of the level at which they are initiated—will interact with each other for the duration and wherever they are implemented". Furthermore, she shows that adaptation and mitigation have a greater temporal (and spatial) overlap [17] (p. 169) than hitherto described in the literature (e.g., Reference [25]). Examples could include countries that adopt a national policy to foster renewable energy, which at that local level will interface with local ecosystems and species that need to adapt to rapid climate change, or the interaction between biofuels and food production [17]. Biesbroek and colleagues [3] comment that the temporal difference is exacerbated and that there is a growing awareness that proactive approaches to both mitigation and adaptation will prove more effective than reactive approaches to climate change. Others exceptions regarding the dominant focus are, for instance, that many mitigation actions would have short-term benefits such as reduced air pollution or, in some 'no-regrets' cases, economic benefits and jobs [3,6,11,17,21]. Alternatively, adaptation actions taken may also have long-term benefits [3,11], as is the case of all large (infrastructural) adaptation measures with a lifetime of centuries or more [17]. Lastly, Biesbroek and colleagues [3] add that the temporal difference over time will be highly influenced by technological development, innovation and scientific progress, but it is unknown if it will increase or decrease this gap.

Thirdly, there used to be a sharper division between adaptation and mitigation in the sectors, but the reality is that both are relevant more or less in all sectors, which is why no exceptions have been emphasized in Supplementary 1. Nevertheless, adaptation is mentioned as being most relevant with regard to the agricultural, forestry, tourism, urban, and coastal zones, as well as to nature conservation, health and water management [11,20,74]. Hence, there is a wide spectrum of sectors which involve a very dispersed set of stakeholders across several scales [19], and where spillover effects occur between sectors [27]. Mitigation, on the other hand, is sectorally less complicated, as the focus is on the large emitters, which are energy, transport, industry, waste, and housing (e.g., [9,19,21,33,69]. Nevertheless, it went from almost being only an energy sector issue to be addressed in all emitting activities in all sectors, as it is judged to be necessary to stay within the 2 °C limit [21]. For instance, more recently there has been a growing interest in the water and land management (agricultural and forestry) sectors as well [11,20,21,74], and renewable energy sources such as biofuels, hydropower, wind energy and solar energy [11] are naturally important substitutes for fossil-fueled energy sources. In most countries, renewable energy sources are found in the energy sector, but they are also relevant as direct energy sources in all other sectors (e.g., solar-driven water pumping systems in agriculture).

Finally, mitigation and adaptation use very diverse units of measure, which makes it difficult to compare them. Mitigation is easily measured using internationally accepted methods [3] and provides hard, quantitative metrics [16,21] that are expressed in CO2 equivalents for individual mitigation actions. These can be compared, as a common currency [14], with other mitigation activities, and if the costs of implementing the measures are known, their cost-effectiveness can be determined and compared [6,76]. In contrast, adaptation has been said to be complex, messy and context-specific, without a standardized measurement methodology, without predefined targets, and is difficult to quantify or express in a simple metric, thus impeding cost–benefit comparisons between adaptation efforts, or with mitigation [3,6,16,21,76]. For instance, "adaptation options cover such a broad spectrum of costs and benefits that the definition of a common currency is far more ambiguous, if not impossible" [14] (p. 375). Furthermore, most of the adaptation measures that are applied are similar to broader sustainable development actions, which is why, for instance, the Adaptation Fund has struggled to come up with appropriate metrics for adaptation. Consequently, most funds accept some actions in the projects that are similar to development activities, without being explicitly designed to target climate change [21].

4.2. Linking Adaptation and Mitigation in Agriculture and Forestry

As identified in Section 4.1, adaptation and mitigation are relevant for almost all sectors. However, relevance is not the same as complementarity or synergy, because adaptation and mitigation can be separated spatially and/or temporally in a sector, or have trade-offs. However, it has been assessed to be highly relevant in the sectors of agriculture and forestry (Supplementary 1), which have been called the obvious candidates for the linking of adaptation and mitigation [5,6,9,11,18,21,77,78]. This can be explained by the fact that adaptation and mitigation are highly relevant for almost all agricultural and forestry activities, and that in most cases these activities have implications for both adaptation and mitigation. Furthermore, there is the substantial resource relatedness and resource complementarity between adaptation and mitigation measures in the land-use sectors [6].

Agriculture and forestry are inextricably linked to both adaptation and mitigation in climate change, as they are highly affected by climate change and, at the same time, contribute significantly to the world's greenhouse gas emissions. The IPCC estimates that agriculture, forestry and other land-use were responsible for 24% of global anthropogenic emissions of greenhouse gases in 2010 [79]. Around 10–12% came from agriculture [80,81] and 10–13% from changes in land use and land cover. The latter is mainly driven by deforestation associated with food production [82], which is expected to increase with growing demands for food [83]. More positively, the mitigation potential of these sectors is estimated to be substantial, and both are important players in closing the gap between the current emissions trend and the politically agreed 2 °C limit. Agriculture and forestry can contribute 32% (17–43%) of what is needed, which is more than other sectors: power (18%), industry (18%), transport (12%), buildings (13%), and waste (5%) (Using a mean estimate. Figures used in making the estimates are from UNEP [80] (p. xv). These reductions are achievable through improved agricultural management practices [67,84] and appropriate forest management [82]. In the case of agriculture this could be achieved through climate-smart agriculture [85–87], climate-smart landscapes [88,89], organic agriculture mitigating climate change [90,91], conservation agriculture [92–94], ecological intensification [95] and sustainable intensification [96,97]. For forests this could include forest conservation, protected area management, afforestation and reforestation, bioenergy plantations, agroforestry, sustainable forest management, and urban forestry [15,98].

Related to adaptation, the IPCC estimates that agricultural production and food security are already being affected by climate change [99]. Land-use systems globally are expected to change in response to future climate change, which will cause significant changes in livelihoods and landscapes [100]. The demand for food is increasing as a consequence of population growth, and at the same time crop yields are declining, which is putting extra pressure on the fertility of the land and will increase prices for the main staple foods [101–103]. One meta-analysis of regional climate impacts on agriculture predicts an 8% decline in overall crop productivity by 2050, which will affect food security significantly [104]. Smallholders practicing rain-fed farming in tropical regions are particularly exposed to climate change and low food security [61,104–106]. Furthermore, their vulnerability will increase when food prices rise because they typically buy more food than their agricultural systems produce. Consequently, the pace of climate adaptation measures in the agricultural sector needs to speed up [99].

Adaptation in relation to forests can, according to Locatelli and colleagues [20], be divided into 'adaptation for forests', which are the needs and actions that will maintain its functioning status, and 'forests for people's adaptation', which is the role forests play in the adaptation of communities and the broader society. Concerning 'adaptation for forests', studies have shown that measures are needed to adapt forests to future climates, since forest ecosystems can be vulnerable to climate variability and climate change, but studies have also revealed that forest projects rarely consider adaptation [107–110]. Regarding 'forests for people's adaptation', studies have estimated that forests contribute significantly to rural livelihoods in many countries [111] and that forest products provide safety nets for local communities when agricultural crops fail, for instance, as a consequence of climatic events [112]. Thus, forests are central to the adaptive strategies of local communities and well-managed ecosystems can

help local communities and the wider society to adapt both to current climate variations and to future climate change by providing a wide range of ecosystem services that reduce the vulnerability [113–116]. For instance, hydrological ecosystem services imbedded in forest systems as base flow conservation, storm flow regulation and erosion control are of the utmost importance in buffering the impacts of climate change on water users [20].

Supplementary 2 [6,9,11,16,18,20,57,63,67,68,74,100,107,117–129] provides a variety of examples of synergies and trade-offs between adaptation and mitigation in the agricultural and/or forestry sectors, which all originate from the literature. However, the examples greatly depend on their context, design and implementation, with site selection and management practices being especially essential. What is intended to be a synergy can turn out to have only neutral or even negative impacts on the other objective. Thus, actions have to be tailored to the specific conditions [130], as few if any outcomes are universal [131]. For instance, it is very difficult to assess how susceptible community livelihood conditions are to a forest carbon sequestration project if extraction happens informally (or even illegally), thereby affecting carbon sinks and hence mitigation efforts [5]. The examples in Supplementary 2 indicate that the forestry sector delivers more synergies and has more trade-offs when compared to agriculture. It could be that this disparity derives from the fact that forest areas contain significantly more carbon, but at the same time they also compete with alternative land-uses (mainly agriculture) that have significant higher opportunity costs [132].

5. Research Gaps

The adaptation–mitigation dichotomy described in Section 2 is also reflected in research, as demand-driven research should be policy-relevant, as a consequence of which it has followed the language and the structure of the UNFCCC's Framework Convention [3,14]. Studies rarely analyze the consequences of their primary domains for the other objective, for example, the impacts of adaptation options on greenhouse-gas emissions. Also, the adaptation and mitigation science communities, which principally are separate and unconnected, tend to use different methods [6]. The mitigation research community has mainly used a 'top-down' approach with a strong focus on technological and economic issues, while the adaptation research community has been more interdisciplinary by nature, tending to conduct 'bottom-up' studies with the emphasis on local and place-based analysis [3,6]. The latter has shared its "research approach with the development studies and disaster risk-reduction communities that minimizes immediate- and short-term impacts of climate trends and shocks in the most vulnerable, primarily developing, countries" [16] (p. 254). These facts have influenced how the two are perceived by policy-makers and the wider public, where adaptation science is assumed to be a soft, uncertain science compared to mitigation science, which has a hard, indisputable reputation [4]. These differences have created difficulties in finding common ground, which has affected the focus on linking of adaptation and mitigation in the world of science [3].

The scientific literature on linking has been dominated by theoretical analysis and modeling of the possible synergies and trade-offs on the global scale. To start with, it was modeling studies of the optimal mix between adaptation and mitigation that was interesting (e.g., reference [12]), as the two objectives were seen as substitutes, rather than complementarities or synergies [3,9,13,17]. However, the optimal mix models proved to be a misguided assumption, as it is impossible to determine 'the' optimal mix of mitigation and adaptation options: Whatever mix is optimal will depend on local conditions, values, preferences, uncertainties, etc. [13]. Later the focus shifted to integrated assessment modeling, which provides approximate estimates of the relative costs and benefits (mainly of mitigation) at highly aggregated levels, whereas only a few models include feedbacks from the impacts of climate change [6]. However, these approaches were met with some criticism, for instance, that many of the adaptation aspects are "inherently difficult to capture in global scale simulations", and that the studies "fail to account for adaptation limits and the context-specific nature of adaptation", "often assume that societies are optimally adapted to their climates, whereas in fact many adaptation deficits currently exist", "tend to underestimate damage costs and adaptation costs, and to overestimate

the potential for adaptation", and "[are] detached from the reality of decision-makers" [46] (p. 6 and 15). Nevertheless, it was commented that the growing awareness and that society plays a far greater role than previously assumed, has led to "a gradual shift from the fundamental and mono-disciplinary research domain towards a more transdisciplinary research strategy" [3] (p. 232). This was an essential change in science in finding socially accountable solutions, which is assessed to be located in the interaction between the theoretical and applied science communities [6,11,133]. However, a drawback of this process proved to be the vast amount of research being conducted on climate change, which has often increased the demand for more knowledge, as more remains unexplained for scientists and politicians. This has created a failure to act upon existing knowledge or a 'mitigation–adaptation paradox' [3].

Thus, discussion of the linkages between adaptation and mitigation is just only getting started, and studies are increasingly beginning to view the two as complementary to each other [21]. Nevertheless, this new paradigm in the linking studies, which truly gained momentum in 2007, was chiefly fueled by the IPCC, who stated that despite having a small literature base, linking was a new research field that was growing fast [6]. Other publications that had an impact on establishing this research area included two special journal issues, particularly Mitigation and Adaptation Strategies for Global Change (Issue 5, 2007) entitled 'Challenges in Integrating Mitigation and Adaptation as Responses to Climate Change' (e.g., References [15,19,27,134,135], and to a lesser degree Climate Policy (Issue 4, 2007) entitled 'Integrating climate change actions into local development' (e.g., References [11,14]. The latter focused more on linking climate change and sustainable development than on linking adaptation and mitigation, as in the former.

Thus, the research on linking strategies was being broadly recognized in 2007, but it had taken a long time, as calls for this to happen can be traced all the way back to 1991 [27]. Since 2007, the amount of research and the resulting evidence base has remained rather scattered [18,21], and as a field of research it is very poorly developed, particularly concerning material at the regional and sectoral levels [22]. The main lack is empirical examples of local, on-the-ground case studies that can improve our understanding of the synergies and trade-offs between adaptation and mitigation [5,6,14,17,20,21]. However, it is not studies narrowly focusing on climate change that are required so much as the current linking paradigm's search for 'triple wins', which is why development issues have to be taken into consideration as well [18,22]. Adaptation and mitigation are too commonly examined separately, as the historical dichotomy between adaptation and mitigation still persists, and if they are studied together, it is in the absence of development issues [18]. Thus, there is a need to move beyond the single-impact focus if studies are to provide a better understanding of the possibilities of mainstreaming multiple 'wins' and to avoid trade-offs in projects and policies [18,21].

However, the potential for and feasibility of multiple 'wins' remains rather uncertain [22], as almost no evidence exists with which to assess them [18]. Also, little is known about the enabling conditions for design and implementation to move from the current dichotomized approach to the synergy approach [5]. Furthermore, the current analytical frameworks for evaluating the links between adaptation and mitigation are inadequate, which is why it is difficult to take advantage of synergies or to explicitly evaluate trade-offs [6]. A strong evidence base on linking can ensure that funding is invested effectively, for instance, in 'no-regret' options that deliver multiple co-benefits for adaptation, mitigation and development. The lack of an evidence base for practices that will achieve triple wins will significantly limit the capacity of donors to identify, monitor and evaluate investments [18,22]. Furthermore, studies of linking may "save money by making more efficient use of scarce resources, e.g., not building separate institutions and processes to support adaptation and mitigation and avoiding conflicting policies" [18] (p. 38).

Finally, the need for empirical case studies mentioned above can function as showcasing in tackling "any concerns related to potential inefficiencies and to address other remaining challenges in for example project planning" [21] (p. 4). For instance, comparative studies of the impacts of carbon projects on local communities and their adaptive capacity are required, as they "are needed to grasp the

necessary lessons and develop best practices for mainstreaming adaptation and mitigation" [20] (p. 444). The identification of barriers to implementing adaptation and mitigation like behavioral change are some of the other prominent examples of the research needed in this area [17,61]. Additionally, the need has been raised for potential synergies and overlaps between existing portfolios, as this could help to adjust funding guidelines to allow for synergies and to avoid trade-offs [21].

6. Implications for Policy

This article documents the need to create incentives at the institutional level for improving the linking of adaptation and mitigation in the implementation of climate-related activities. The dichotomy between adaptation and mitigation, which is mainly a politically and scientifically constructed one, is found to be prevalent. Thus, even though the focus has changed, interlinkages between adaptation and mitigation have started to gain attention. However, institutions may be somewhat intimidated in linking adaptation and mitigation, as it is far from easy to manage. It can be compared to a hedgehog, as it sticks out (in many directions) and moves slowly only in the dark (lack of frameworks and clear concepts), which is why it can easily be run over (by separate measures or 'doing nothing'). Nevertheless, by making changes that prioritize this integration, the institutions involved can create the potential to pursue the advantages highlighted. On the other hand, if incentives are not put forward politically and financially, this can create inefficiency, and we may find ourselves following approaches that solve one issue but exacerbate others.

However, politicians also have a responsibility to disregard the short time-horizons of terms and for creating systems that are manageable in practice. In addition, linking adaptation and mitigation should only be attempted in cases with spatial, temporal and sectoral overlaps, and in activities that have the potential to develop complementarity and synergy. Some climate measures have no complementarity or synergy, maybe even trade-offs, but if they are essential, they have to be implemented nevertheless, and disfavoring these measures in the pursuit of linking adaptation and mitigation should be avoided. Moreover, since cost-efficiency is still crucial in making them attractive to stakeholders and funding agencies, then all activities in climate measures have to contribute substantially to an objective (adaptation or mitigation)—and they shall consequently not just be far-fetched activities making an unimportant link between adaptation and mitigation.

Supplementary Materials: The following are available online at http://www.mdpi.com/2073-445X/7/4/158/s1. Supplementary 1: The dominant focuses of adaptation and mitigation, including deviations and Supplementary 2: Examples of synergies and trade-offs between adaptation and mitigation in the agricultural and/or forestry sectors

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