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Research Article

Carbon Taxation as An Instrument to Promote Wildfire Prevention and Avoid Biodiversity Loss in Portugal: An Order of Magnitude Analysis

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Abstract

Climate change is one of the main challenges of the current century. Emissions taxes are one of the proposed ways to help in addressing this issue. In this sense, Portugal has introduced an Addition Tax on Carbon Emissions through Law N. 82-D/2014. One of the most notorious impacts of climate change in the country is the wildfires increasing in frequency and intensity. Forests provide various ecosystem services not valued by traditional markets, such as carbon sequestration. Recently, Portugal has created new environmental policies that deal with fire prevention and biodiversity conservation through payment for ecosystem services schemes. In this context, the objective of this work was to perform an order of magnitude analysis of the revenue from the Addition Tax on Carbon Emissions (Law N. 82-D/2014) and contrast it with the investment costs of RCM N. 121/2019 (Payment for Ecosystem Services) and of RCM N. 59/2017 (Prescribed Burning Program). The results indicated that the Addition Tax revenue was much greater than the costs of the other two policies combined, even if expanding the

use of prescribed burning in the country. This suggested that these policies can work synergistically, as development agendas recommend, such as the Sustainable Development Goals. This analysis framework might be helpful for other countries, especially in the Mediterranean Basin.

Keywords
Climate change; carbon taxation; biodiversity; ecosystem services

1. Introduction

Climate change presents one of the most significant challenges for humanity in the twenty-first century. One way to reduce greenhouse gas emissions, suggested by economic theory, is to introduce an emissions tax to internalize its social costs [1]. In Portugal, this type of taxation was introduced by Law N. 82-D/2014, which changed environmental taxation rules in the sectors of energy and emissions, transport, water, waste, land use, forests, and biodiversity, introducing a tax regime for plastic bags and an incentive regime for the disposal of vehicles at the end of their lifecycle, as a reform part of environmental taxation.

In Article 92.º-A, the Law created the Addition Tax on Carbon Emissions applied to specific energy and petroleum products. According to this Law, the value of the tax for each year(n) is calculated in the previous year (n-1) as the arithmetic mean of the price resulting from auctions of greenhouse gas emission allowances, carried out within the framework of the European Union Emissions Trading System (EU ETS), between July 1st of year n-2 and June 30th of year n-1. The Addition Tax value has varied from 6.67 €/Mg of CO_2 (2016, when it started) to 23.921 €/Mg of CO_2 (2022, present date). Table 1 shows the evolution of the tax values through the years.

Table 1 Addition Tax on Carbon Emissions through the years.

Year	Addition Tax (€/tCO_2)	Source
2016	6.670	(Ordinance N. 420-B/2015, 2015) [2]
2017	6.850	(Ordinance N. 10/2017, 2017) [3]
2018	6.850	(Ordinance N. 384/2017, 2017) [4]
2019	12.740	(Ordinance N. 6-A/2019, 2019) [5]
2020	23.619	(Ordinance N. 42/2020, 2020) [6]
2021	23.921	(Ordinance N. 277/2020, 2020) [7]
2022	23.921	(Ordinance N.º 249-A/2022, 2022) [8]

The Addition Tax has consistently been increasing or maintaining its value through the years. This is largely due to the context following The Paris Climate Conference (COP21), which has led the prices of carbon permits to rise to all-time highs after EU leaders reached a deal on more ambitious emissions cuts for this decade [9]. The income from this taxation is directed to the Portuguese Environmental Fund (created by Decree-Law N. 42-A/2016), which was designed to sponsor sustainable development actions in the country, such as climate action and biodiversity protection. Despite being an intrinsic part of Mediterranean ecosystem dynamics, wildfire is one of the

notorious consequences of climate change in Portugal as it increases the occurrence and intensity of fire events [10, 11], which altered carbon cycles by increasing the atmospheric carbon dioxide (CO_2) and decreasing the sequestration by terrestrial ecosystems, thus negatively affecting biodiversity in Portugal [12-14].

There is growing consensus among the participating countries and organizations of the United Nations Climate Conference that forestry is an effective way to mitigate climate change. Forests can aid in tackling climate change by decreasing greenhouse gas emissions and increasing their absorption, acting as a carbon sink, storing carbon-containing chemicals for indefinite periods [15]. Climate change adaptation is no different from disaster risk reduction, and actions to tackle it should be aligned with other sustainable development policies [16]. In this sense, various global policies address the issues that arise from climate change and the increase in forest fires, such as the United Nations Sustainable Development Goals (SDGs), namely Goal 13 – Climate Action and Goal 15-Life on Land, that relate climate regulation and biodiversity issues [17]. The implicit logic in SDGs is that the goals depend on each other [18] and should be addressed in a coordinated manner.

In alignment with the European guidelines, Portugal has developed policies to tackle climate change, wildfires, and biodiversity recovery in the past decades. Portugal signed the Kyoto Protocol in 2002, and the Resolution of the Council of Ministers (RCM) N. 56/2015 approved the Strategic Framework for Climate Policy, the National Program for Climate Change, and the National Strategy for Adaptation to Climate Change. Regarding wildfires, RCM N. 59/2017 approved the National Prescribed Burning Program, aiming to reduce the fire events' extensions. This policy not only helped avoid losses in terms of biodiversity, real state, and, potentially, lives, but also reduced overall fire emissions in some Mediterranean countries like Portugal through prescribed burning [11, 14]. Table 2 shows the potential benefits in terms of wildfire CO_2 emissions reduction when applying prescribed burning in some Mediterranean countries.

Table 2 Expected reduction in wildfire CO_2 emissions by applying prescribed burning in Mediterranean countries. Adapted from: Narayan et al. [14].

Country	**Absolute emissions reduction under the prescribed burning scenario (million tonnes CO_2)**	**Percentual emissions reduction under the prescribed burning scenario**
Algeria	0.361	46%
Cyprus	0.012	46%
France	0.46	46%
Israel	0.002	50%
Italy	0.929	46%
Morocco	0.021	47%
Portugal	0.936	46%
Spain	0.465	46%

As for biodiversity, following the European guidelines, RCM N. 55/2018 approved the National Strategy for Nature Conservation and Biodiversity 2030, which recognizes that forest fires threaten biodiversity and states that Portugal should be in the vanguard in economically valuing ecosystem

services. In this sense, RCM N. 121/2019 instated the country's first Ecosystem Services Payment Program in Rural Spaces. This policy aimed to recognize many significant contributions of forests, which are not valued by common markets, such as erosion control, carbon sequestration, regulation of the hydrological cycle, conservation of biodiversity, reducing susceptibility to fire, and improving landscape quality.

These policies are based on the increasing scientific evidence and understanding of climate change and forests' roles in the carbon cycle. To materialize actions to reduce CO_2 emissions by the forests, the landowners need to be rewarded appropriately through economic incentives [19]. It is known that by institutionalizing incentives for carbon sequestration, for example, a more robust economic rationale can be made for expanding forest restoration [20]. In this context, carbon taxation has been suggested as a means to fund forest conservation measures around the world [21], and through new governance arrangements, climate change and forest policies, both for adaptation and mitigation, can be addressed jointly [22].

Portugal has a sound regulatory framework regarding climate change, biodiversity, and forest fire management, and there is a literature suggesting that a tax on fossil fuels can support the restoration of ecosystems that help curb climate change [21]. In this context, the objective of this study is to perform an order of magnitude analysis of the revenue from the Addition Tax on Carbon Emissions (Law N. 82-D/2014) and contrast it with the investment costs of RCM N. 121/2019 (Payment for Ecosystem Services) and of RCM N. 59/2017 (Prescribed Burning Program). The idea is to make a "big picture" analysis of the possibility of these policies working synergistically, further aiming to address climate change. As Portugal is considered as a characteristic representative of the Mediterranean region for forest-management interventions [23], this analysis can be a useful approach for other countries in the region and perhaps in other mediterranean-climate regions of the world.

2. Materials and Methods

An order of magnitude analysis provides efficient integration of quantitative and qualitative knowledge in the expression and solution of engineering problems. It provides an initial approximation of the problem, serving as a framework to model the situation under study. The order of magnitude analysis is based on seven primitive relations among absolute magnitudes of quantities: "much less than" (< <), "moderately less than" (− <), "slightly less than" (∼ <), "equal to" (= =), "slightly greater than" (> ∼), "moderately greater than" (> −), and "much greater than" (> >) [24]. The structure of the main order of magnitude analysis employed in this study is shown in Figure 1.

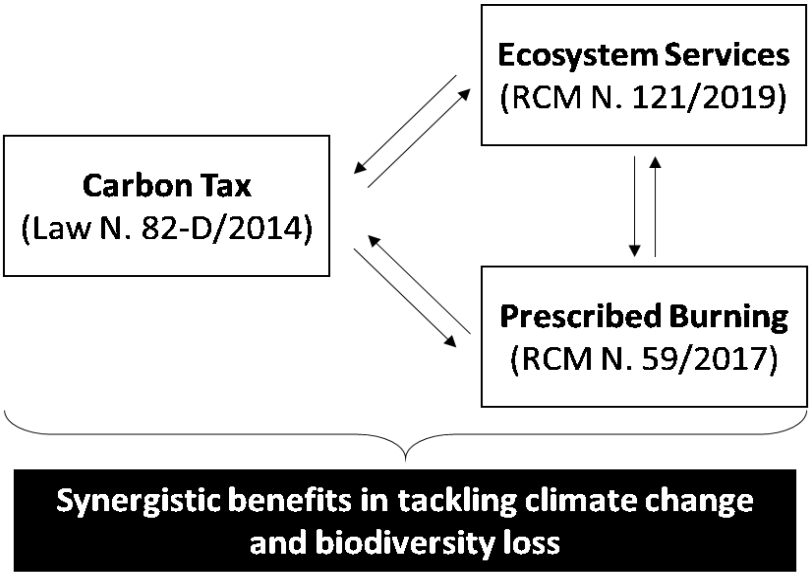

Figure 1 Comparison of the revenue and costs of each policy, searching for possible synergistic benefits.

The Addition Tax revenue (Law N. 82-D/2014) was obtained from 2016 until 2018 through a report from the Technical Unit of Budget Support [25]. The cost of the Payment for Ecosystem Services policy was obtained in Notice N.13655/2019 (associated with RCM 121/2019), which accounts for the entire duration of the policy from 2019 until 2038. As for the prescribed burning policy, its costs for 2017 and 2018 are estimated in the National Prescribed Burning Plan [26], which was part of the National Prescribed Burning Program (RCM N. 59/2017).

The analysis is also further expanded beyond the current policies in place to assess the economic and carbon benefit of promoting larger use of prescribed burning in Portugal. This is done by using previously published data [14], prescribed burning costs in Portugal [26], and the Addition Tax values through the years.

3. Results

Figure 2 shows the order of magnitude analysis of revenue from the Addition Tax in contrast with the costs of RCM N. 59/2017 and RCM N. 121/2019.

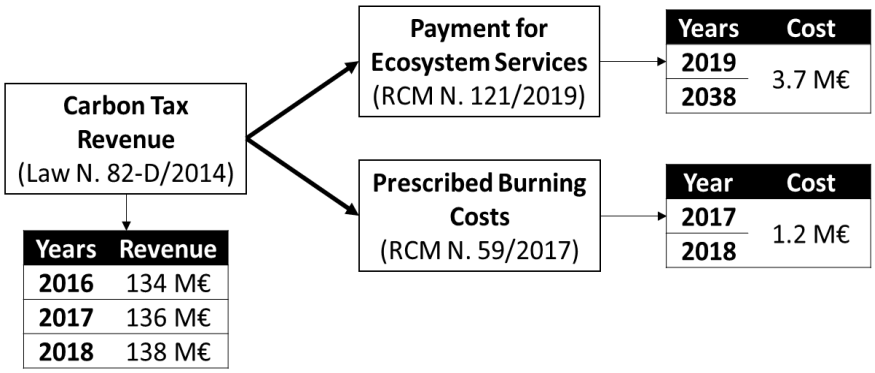

Figure 2 The contrast of the revenue from carbon taxation and investment costs for prescribed burning and biodiversity conservation.

From the information gathered in this order of magnitude analysis, despite the different timeframes analyzed, it was clear that the revenue from the Addition Tax was "much greater than" the costs of the Payment for Ecosystem Services and Prescribed Burning policy. It should be emphasized that in 2019, the Addition Tax almost doubled when compared to 2018, but the amount collected is not yet publicly available.

Expanding the analysis on the economic benefits of further employing prescribed burning, the typical treatment regime is to apply it annually in an area amounting to 5 – 10% of the area annually burned by wildfires [14]. The Portuguese National Prescribed Burning Plan estimated that the prescribed burning cost was in the order of 120 euros per hectare [26]. Narayan et al. [14] have estimated that the average area burned over a 5-year period in Portugal was around 174000 ha.

In this context, assuming that 10% of the annually burned area will be treated with prescribed burning, this would imply a cost of around 2.1 M€ per year. To estimate the carbon benefits associated with the use of prescribed burning in Portugal, the Addition Tax values through the years (Table 1) were multiplied by the emissions reduction expected in Portugal (Table 2). Figure 3 shows the expected benefits through the years.

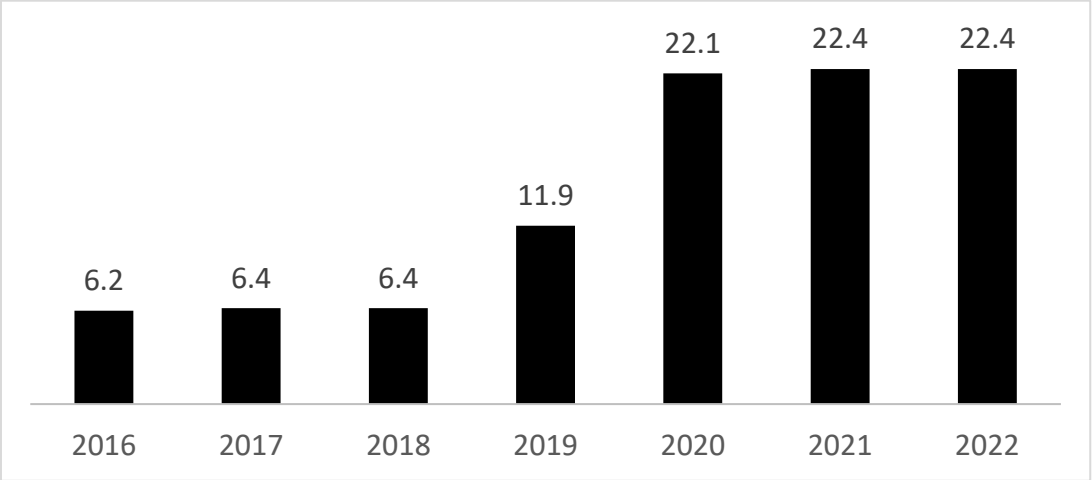

Figure 3 Expected savings in terms of avoided carbon emissions for Portugal according to the Addition Tax value through the years. Values are in millions of euros per year.

As the Addition Tax values have increased, so did the benefits associated with avoided carbon emissions, which have varied from 6M€ per year reaching over 22M€ per year.

4. Discussion

As is recognized by the European Commission, the biodiversity crisis and the climate crisis are directly connected. Climate change accelerates the destruction of the natural world through more extreme climatic events, such as wildfires, while the loss and unsustainable use of nature are drivers of climate change [27]. Under these harsher climate conditions, it is likely that current fire suppression cannot control all wildfires, and its capability to do so might be compromised [10]. This justifies the need to proactively invest in wildfire prevention, whether through prescribed burning or biodiversity conservation investment.

Currently, the Addition Tax revenue is directed to the Portuguese Environmental Fund. Table 3 shows the types of actions that the Fund can sponsor.

Table 3 Actions sponsored by the Portuguese Environmental Fund. Source: Environmental Fund [28].

Scope of projects funded by the Portuguese Environmental Fund
Adaptation to climate change
Carbon sequestration
Climate change mitigation
Cooperation in the area of climate change
Efficient use of water and protection of water resources
Encouraging the participation of entities in the carbon market
Fulfillment of national and community goals and targets for urban waste management
Prevention and repair of environmental damage
Protection and conservation of nature and biodiversity
Research and development in environmental matters
Sustainability of water services
Training and awareness in environmental matters
Transition to a circular economy
Use of the carbon market to meet international targets

This Fund was created to support environmental policies aligned with the Sustainable Development Goals, such as carbon sequestration, that can benefit from the implementation of RCM N. 59/2017 and RCM N. 121/2019 actions. Often ecosystem services-based solutions that can help in SDGs implementation are overlooked or underexploited [17]. Currently, Portugal is mainly investing in energy transition and other more structural interventions and not so much in nature-based solutions.

In this sense, further analyzing the benefits of prescribed burning in Portugal, it is possible to determine that the positive effect has progressed from “slightly greater than” in 2016 to “moderately greater than” in 2021 and 2022. At the onset of the Addition Tax, the benefits associated with prescribed burning were around three times larger than its costs, and in the last two years, the benefit has risen to 11 times its costs.

This evidence further suggests that investing in forest management through prescribed burning can be an interesting investment not only in terms of conservation, protection of lives, livelihoods, and infrastructure but also regarding carbon storage. In this sense, prescribed burning can be part of a larger national carbon storage policy.

Finally, despite the possibility of using part of the revenue from the Addition Tax to finance these two policies, there were three main criticisms of funding natural climate solutions through carbon taxes, as pointed out by Barbier et al. [21]. Firstly, they can cause the shift of forest degradation to other areas. Secondly, they may decrease the incentive to reduce emissions via renewable energy. And thirdly, the tax revenue should be used for different purposes. However, the authors believe that all these issues can be addressed. A national tax scheme can reduce the probability of degradation shifts within each country. Renewable-energy production and natural climate solutions are both crucial. Lastly, despite the many worthy uses of tax revenue, the severity of climate change and biodiversity loss makes tackling both a priority.

This is also true in Portugal's case. First, the tax revenues would be used to protect the forest (and the residing population) against extreme fire events, according to the area's vulnerability. Second, as the results demonstrated, the tax revenue far exceeds what is needed to invest in prescribed burning, even its expansion, and biodiversity initiatives, leaving plenty of financial resources to be invested in renewable energies or other climate-focused actions. Lastly, climate actions and biodiversity are top concerns in the European and Portuguese environmental agenda, and therefore both should have a priority in using these funds.

5. Conclusions

This order of magnitude study aimed to provide an initial assessment of the economic viability of using the revenue from the Addition Tax on Carbon Emissions for funding wildfire prevention and biodiversity policies, both in alignment with climate change prevention and mitigation. The expansion of the use of prescribed burning in Portugal was also analyzed.

The present study results indicated that the tax revenue was "much greater than" what was needed for investing in wildfire prevention and biodiversity conservation through the established policies. From an environmental perspective, there was clear evidence of the potential benefits of all these policies and that they could work synergistically since they all had positive impacts in mitigating climate change.

Furthermore, the results indicated that the expansion of the use of prescribed burning implied a "moderately greater than" benefit in terms of carbon storage when compared to the treatment costs. As the Addition Tax value had increased through the years, following the carbon market behavior, larger benefits could be expected.

Finally, this study was by no means exhaustive. More site-specific emissions data could be used to further clarify the benefits of using prescribed burning. Also, the carbon benefits associated with conservation practices and the maintenance of ecosystem services in Portuguese forests should be further explored. This approach provides information and insight, not only to the scientific community, but also to policymakers who will have the basis to best tailor their efforts and choose priorities.

Author Contributions

The author did all the research work of this study.

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Competing Interests

The authors have declared that no competing interests exist.

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