4.5 Living Lab Chile (Biobío Region)

The region of application for this component in the Living Lab of Chile is Biobío, a region that cover 2.4 million ha of which, 568,000 ha are available for receiving fuel treatment projects. The analysis was performed at the level of Municipalities (Subsubcuencas - 89 in total, with an area ranging from 387 ha to 97,170 ha). We analysed the effects of fuel treatment projects at ten management objectives: biomass retrieval, protection of carbon stocks, fire risk reduction at the community exposure sources, protection of community exposure sinks (parts of communities that receive the highest amounts of fire), reduction of fire hazard (i.e., energy release) to facilitate better fire suppression, reduction of future ignitions in high ignition probability areas, reduction of the exposure of protected areas from the sources of their exposure, protection of the most exposed parts of protected areas (sinks), reduction of burn probability (BP) and reduce the downstream protection value (DPV) for community exposure, meaning, finding and treating to areas where a large number of fires cross before reaching the communities.

4.5.1 SET0: Control & Evaluation

In this set of fuel treatment scenario planning, we estimated the effect that spatial optimization has in three management objectives, namely community exposure sources, downstream protection value and ignition probability, when we select to apply fuel treatments at 80,000 ha and we compared with a random and a proximity to roads allocation schemes. We found that both random and roads allocation have very low performance when compared with the optimized allocation (Figure 152).

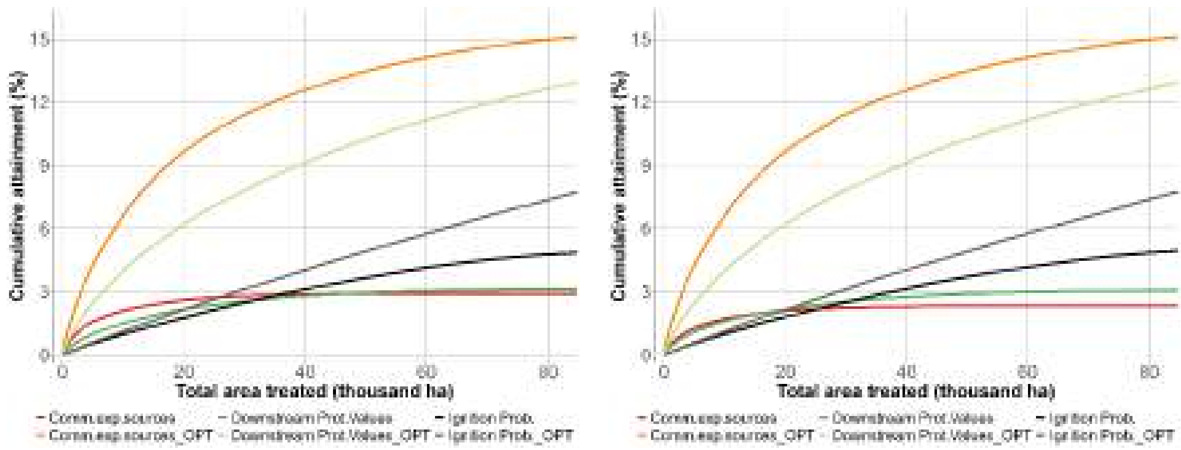

Figure 152 Left: Random project allocation; Right: Project allocation proximate to the road network. OPT: Results from the optimization runs. For comparison, similar colours with different intensity were used for the same objective.

In particular, the optimized allocation for downstream protection value can achieve an attainment of up to 13% (i.e., a reduction of 13% in the total exposure that all communities receive from locations in the study area with high downstream protection value) compared to the 3% the non-optimized allocation achieved, the community exposure sources optimized allocation achieved approximately 15% vs. the 2.5-3% of the non-optimized allocation, and finally, we found smaller differences between the spatially optimized allocation of the reduction of ignition probability that achieved approximately 8% attainment vs. the 5% of the non-optimized allocations. These results prove that the business-as-usual way of allocating fuel treatment projects (i.e., randomly or in proximity to roads) cannot provide substantial reduction to key management objectives like the protection of communities or risk reduction for protected areas and can have a similar impact only for the objective of reducing ignition probability.

4.5.2 SET1: Efficiency, with a 10-year implementation plan

The implementation of a 10-year plan to reduce the fire risk of the communities from the sources of their exposure by treating half (i.e., 140,000 ha) of the lands that are available for treatment and has a value greater than zero for that objective (i.e., 280,000 ha), resulted to request the spatial optimization of 1400 projects (Figure 153).

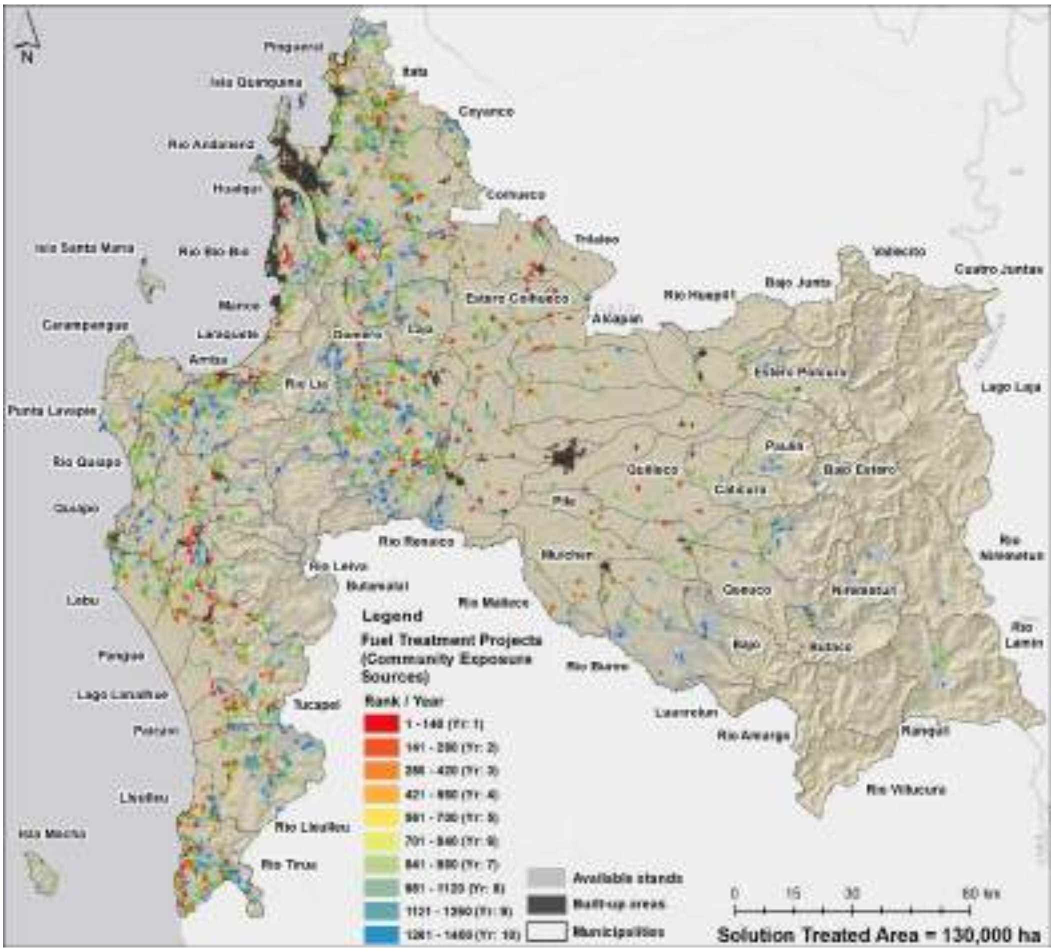

Figure 153 Map of the 1400 projects ranked by the level of attainment they achieve and distributed evenly across each year of the 10-year implementation plan of fuel treatment with the objective to reduce the exposure of developed areas from incoming wildfires (exposure sources).

The total treated area returned from the spatial optimization solution is 130,000 ha. In this optimization run we did not consider any administrative boundary. Each year, approximately 13,000 ha should be treated (Figure 154), and during the first year the main objective (i.e., community exposure sources) can reach an attainment of up to 8%, with all other objectives achieving less than 2.5%. For the first five years, the attainment of the main objective can reach 14.5% by treating approximately 64,800 ha, with the attainment of the other objectives be lower than 6.5%. Except for the protected areas exposure sinks that achieves a low attainment (<3%), the objectives of burn probability, carbon, biomass, wildfire hazard, ignition probability, DPV, and community exposure sinks show a linear and steady increase by year, with BP, ignition probability and wildfire hazard complete correlated. After the fifth year, the attainment for the main objective is slightly increased to reach 15.5% by the tenth year, while the other objectives rise gradually to reach an attainment of ~9% for ignition probability, wildfire hazard, BP and DPV, ~7.5% for the community exposure sinks, 7% for biomass, and 5.5% for carbon. Note that in this LL, biomass and carbon are not correlated and despite we used the same carbon dataset for all Living Labs, here we used the ESA 2020 dataset to retrieve biomass (see methods section). The lower attainment when optimizing for the reduction of the main objective is achieved for the community exposure sinks, that barely reaches 3% by the tenth year.

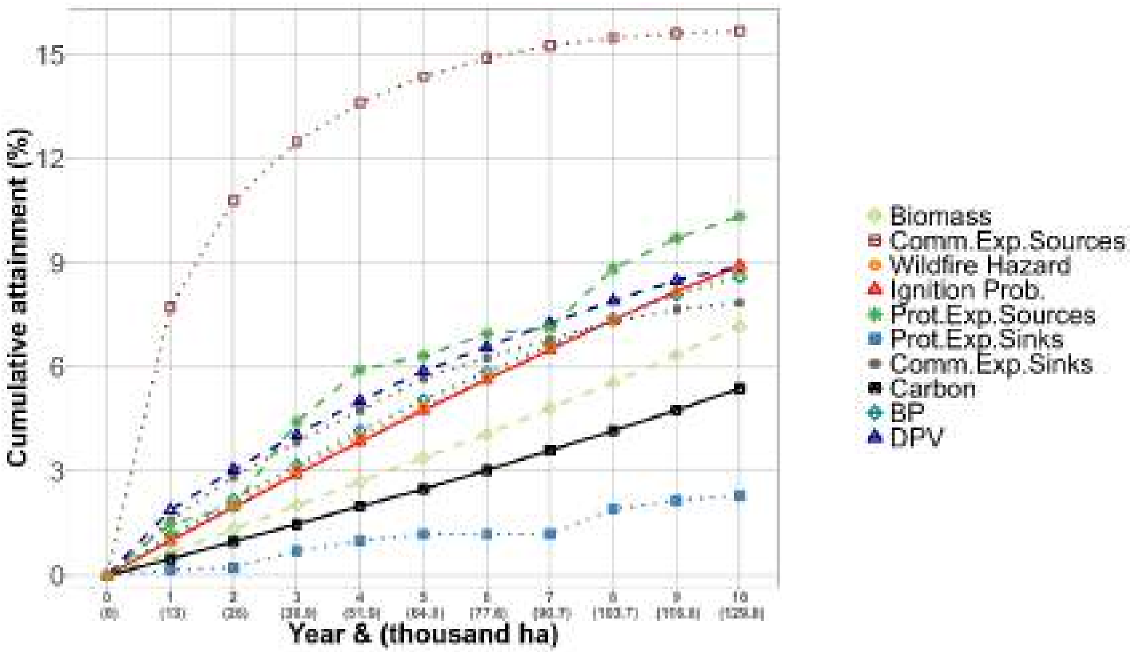

Figure 154 The 10-year implementation plan of fuel treatment with the objective to reduce the exposure of developed areas from incoming wildfires (exposure sources).

The bulk of the projects are in the Municipality of Rio Andalien1 (~8.8k ha), followed by Rio Culenco (8k ha), Rio Lleulleu (~7k ha), Pingueral (~6.5k ha), Rio Tirua (~6.5k ha) and Arriba (~6.2k ha), with the rest Municipalities receiving less than 6k ha of fuel treatments during the 10-year implementation plan (Figure 155-top). The highest attainment is achieved in the Municipalities of Pangue (0.9%), Rio Tirua (0.87%) and Rio Andalien1 (0.87%). Pangue although it received approximately 3k ha of treatments (ranked 12 among all municipalities in total area treated), achieved the highest attainment for that objective. It is notable that the projects planned to be implemented during the first year and are in the Municipalities of Pangue, Rio Tirua, Rio Andalien1 and Rio Bio-Bio achieve at least half of their total attainment (Figure 155-bottom). This finding suggests that they should be among the first to receive fuel treatments to faster achieving the goals of the main objective.

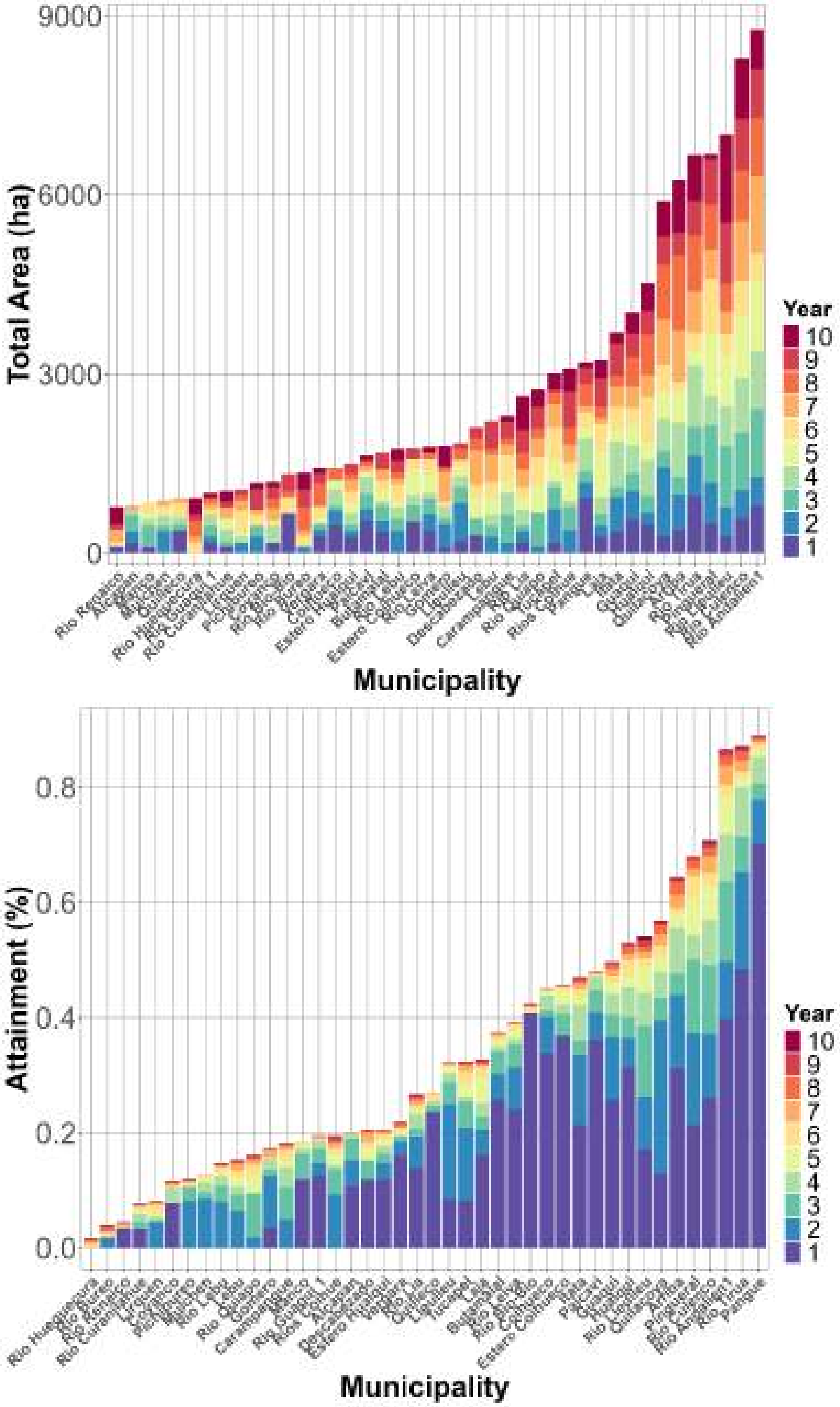

Figure 155 Top: area treated in ha for each Municipality by implementation year. Bottom: main prioritized objective attainment (%) for each Municipality by implementation year.

The implementation of a 10-year plan to reduce the fire risk in areas with high downstream protected value for developed areas by treating half (i.e., 249,000 ha) of the lands that are available for treatment and has a value greater than zero for that objective (i.e., 498,000 ha), resulted to request the spatial optimization of 2490 projects (Figure 156). The total treated area returned from the spatial optimization solution is 233,000 ha. In this optimization run we did not consider any administrative boundary.

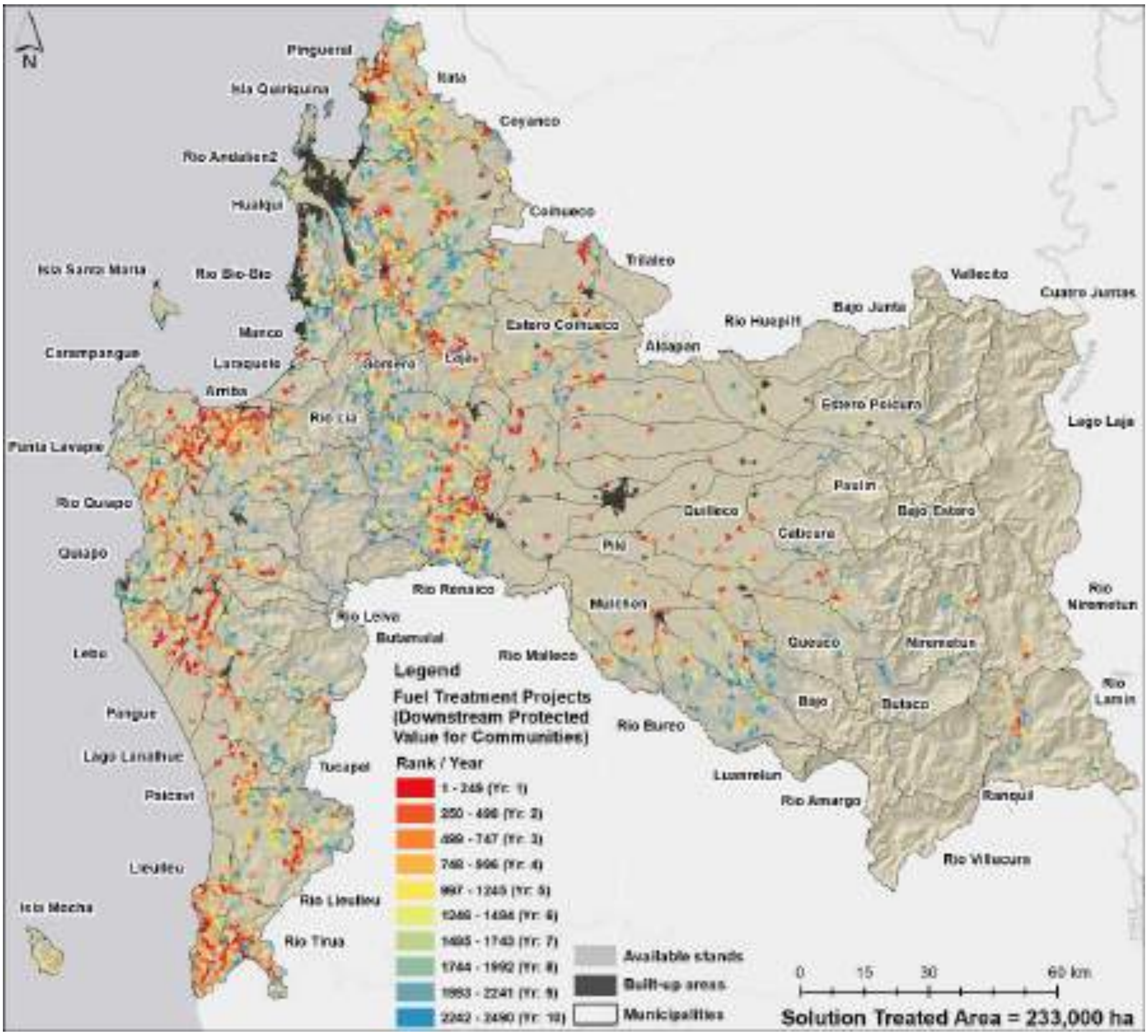

Figure 156 Map of the 2490 projects ranked by the level of attainment they achieve and distributed evenly across each year of the 10-year implementation plan of fuel treatment with the objective to reduce the downstream protected value for developed areas.

Each year, approximately 23,500 ha should be treated (Figure 157), and during the first year the main objective (i.e., downstream protected value) can reach an attainment of up to 8%, with the attainment of the other objectives be low (between 0-2.7%) except for the community exposure sources (~4%). For the first five years, the attainment of the main objective can reach 14.5% by treating 116,400 ha, with the attainment of the other objectives be between 4-9.5% with higher values for community exposure sources and wildfire hazard, while the community exposure sinks is less effective (<1%). After the fifth year, the attainment for the main objective is slightly increased to reach 16.5% by the tenth year, while the other objectives rise with a steady pace to reach an attainment of ~16% for wildfire hazard, 14.5% for ignition probability and burn probability, 13.5% for protected areas exposure sources and community exposure sources, and 12.5% for biomass. The lower attainment when optimizing for the reduction of the main objective is achieved for the community exposure sinks (10%), carbon (9.5%) and community exposure sinks (5.5%).

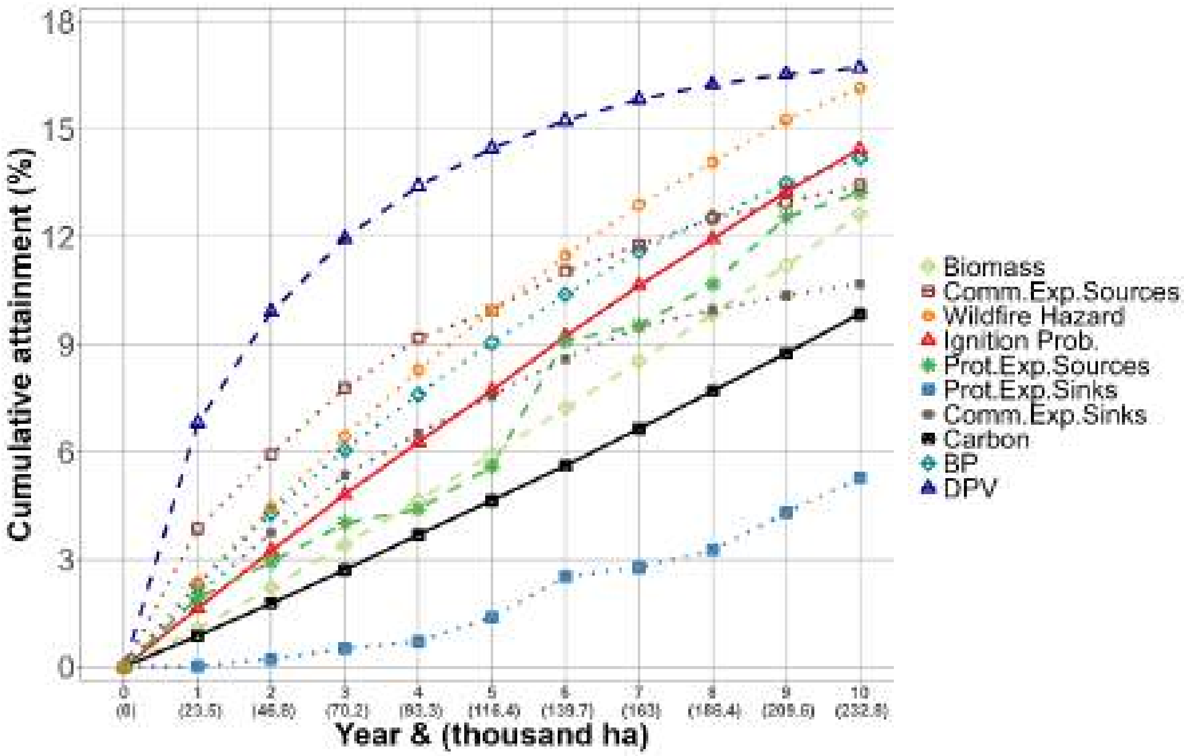

Figure 157 The 10-year implementation plan of fuel treatment with the objective to reduce the exposure of downstream protected value for developed areas.

The bulk of the projects are in the Municipality of Rio Andalien1 (16k ha), followed by Rio Lleulleu (~12.5k ha), Quilacoya and Rio Culenco (11.5k ha), Rio Tirua (~11k ha) and Arriba (~9k ha), with the rest Municipalities receiving less than 9k ha of fuel treatments during the 10-year implementation plan (Figure 158-top). The highest attainment is achieved in the Municipalities of Rio Tirua (1.3%), Arriba (1.1%), Rio Andalien1 (0.9%), Pangue (0.77%) and Rio Lleulleu (~0.75%). Compared to previous mentioned cases in other LLs where the first year was by far the greatest in terms of achieving the best attainment, more than half in several cases, the projects planned to be implemented during the first year and achieve more than half of their total attainment are in the Municipalities of Arriba, Carampangue, Hualqui and Rio Lamin (Figure 158-bottom). Despite this, a great number of Municipalities achieve half of their total attainment by the second year, like the Municipalities of Rio Tirua, Pangue and Rio Andalien1. This finding suggests that they should be among the first to receive fuel treatments to faster achieving the goals of the main objective.

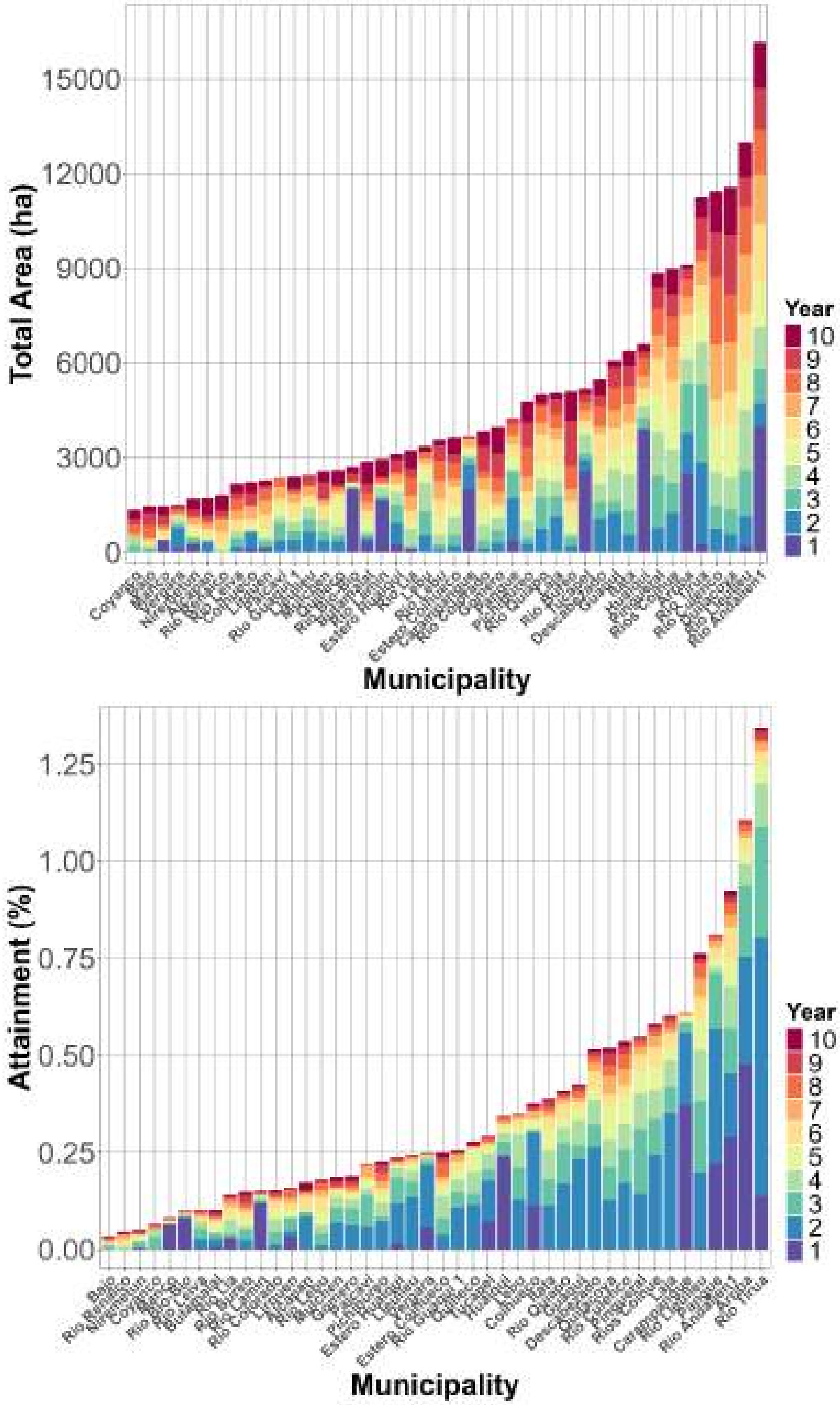

Figure 158 Top: area treated in ha for each Municipality by implementation year. Bottom: main prioritized objective attainment (%) for each Municipality by implementation year.

The implementation of a 10-year plan to reduce the ignition probability by treating half (i.e., 284,000 ha) of the lands that are available for treatment and has a value greater than zero for that objective (i.e., 568,000 ha), resulted to request the spatial optimization of 2840 projects (Figure 159). The total treated area returned from the spatial optimization solution is 269,000 ha. The proposed area for treatments is large since all the available stands had an ignition probability value attached that was greater than zero (the unavailable and non-burnable stands were already excluded). In this optimization run we did not consider any administrative boundary.

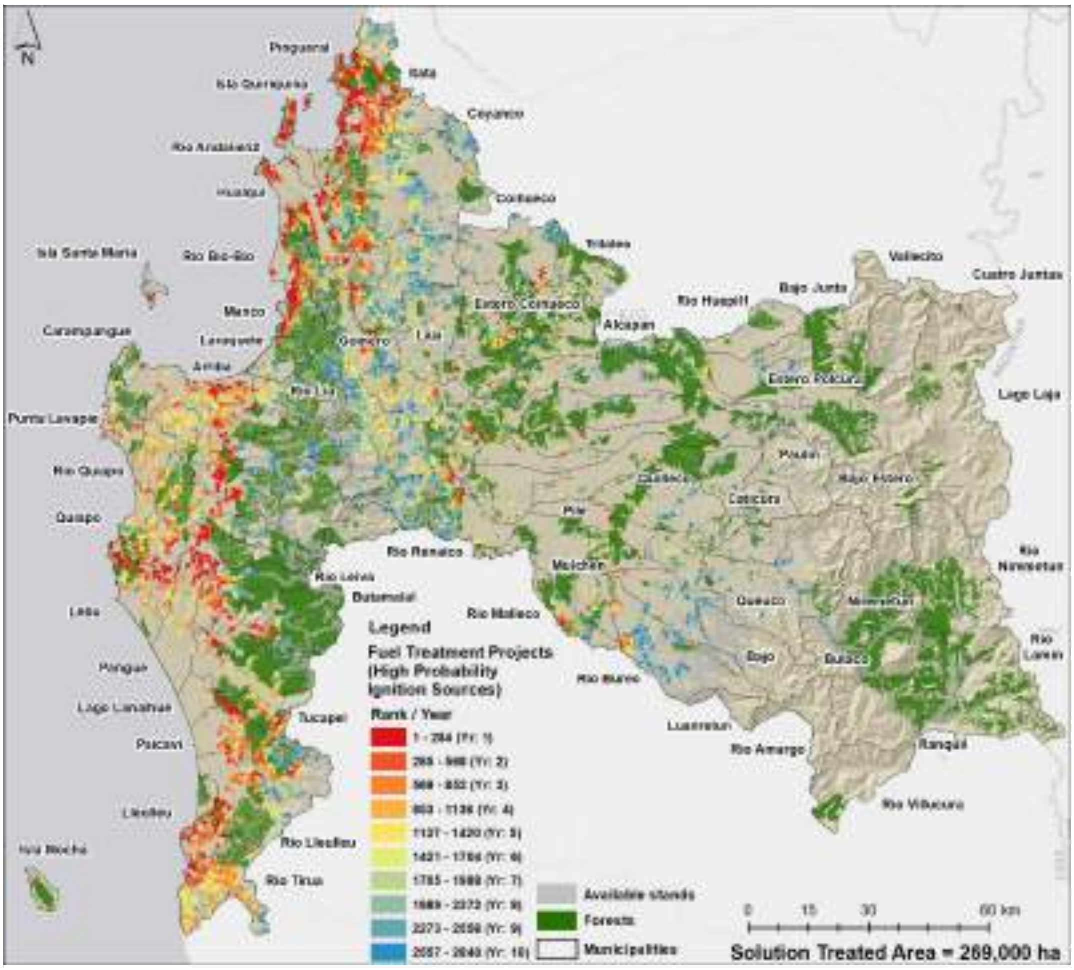

Figure 159 Map of the 2840 projects ranked by the level of attainment they achieve and distributed evenly across each year of the 10-year implementation plan of fuel treatment with the objective to reduce new ignitions by treated in areas with high ignition probability.

Each year, approximately 27,700 ha should be treated (Figure 160), and during the first year the main objective (i.e., reduction of ignition probability) can reach an attainment of up to 3%. For the first five years, the attainment of the main objective can reach ~12% by treating 137,000 ha, with the attainment of the other objectives be between 3.5% (community exposure sinks) and 11% (protected areas exposure sources). High attainment was achieved also by the wildfire hazard (10%). The objectives of community exposure sources and burn probability achieved 9% attainment, while the objective of DPV, biomass and community exposure sinks achieved 8%. Carbon was approximately ~6%. After the fifth year, the attainment for the main objective is linearly increased to reach ~19% by the tenth year, while most other objectives rise linearly. Second in rank is the wildfire hazard with ~18% attainment, followed by biomass and BP (~15%), protected areas exposure sources, community exposure sources and DPV (~13.5%), carbon and community exposure sinks (~11%) and protected areas exposure sinks (6%), all after applying fuel treatments at a massive area of 270k ha.

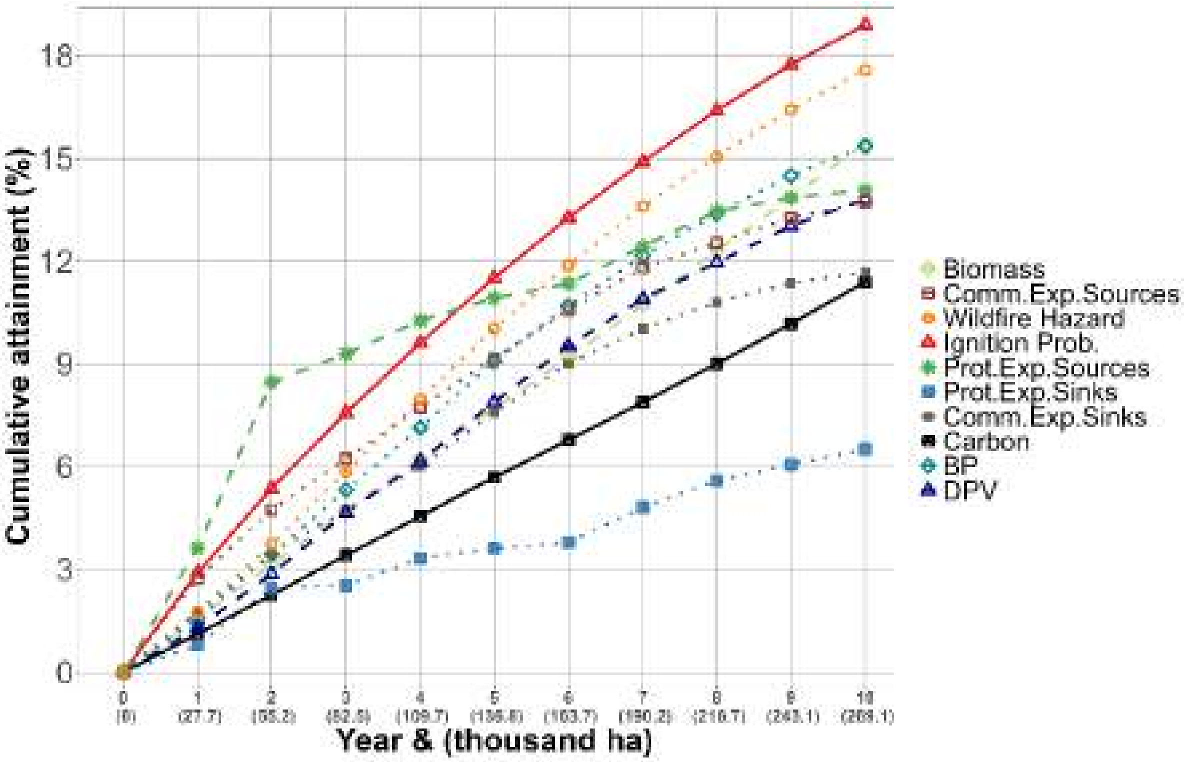

Figure 160 The 10-year implementation plan of fuel treatment with the objective to reduce new ignitions by treated in areas with high ignition probability.

The bulk of the projects are in the Municipality of Rio Andalien1 (~19k ha), followed by Quilacoya (~14k ha), Rio Lleulleu (~14k ha), Rio Culenco (13k ha) and Rio Tirua (~12.5k ha), with the rest Municipalities receiving less than 12k ha of fuel treatments during the 10-year implementation plan (Figure 161-top). The by far highest attainment is achieved in the Municipality of Rio Andalien1 (~1.2%), that also receives a high load of treatments, followed by Pingueral and Rio Lleulleu (~1.1%) (Figure 161-bottom). All other Municipalities achieved attainment <1%. The attainment per year is almost evenly distributed among the 10-year period, except for the Pingueral, Hualqui, Rio Lebu, Pangue, Rio Bio-Bio and Rio Curanilahue that can achieve more than half of their total attainment in the projects applied during the first two years of implementation.

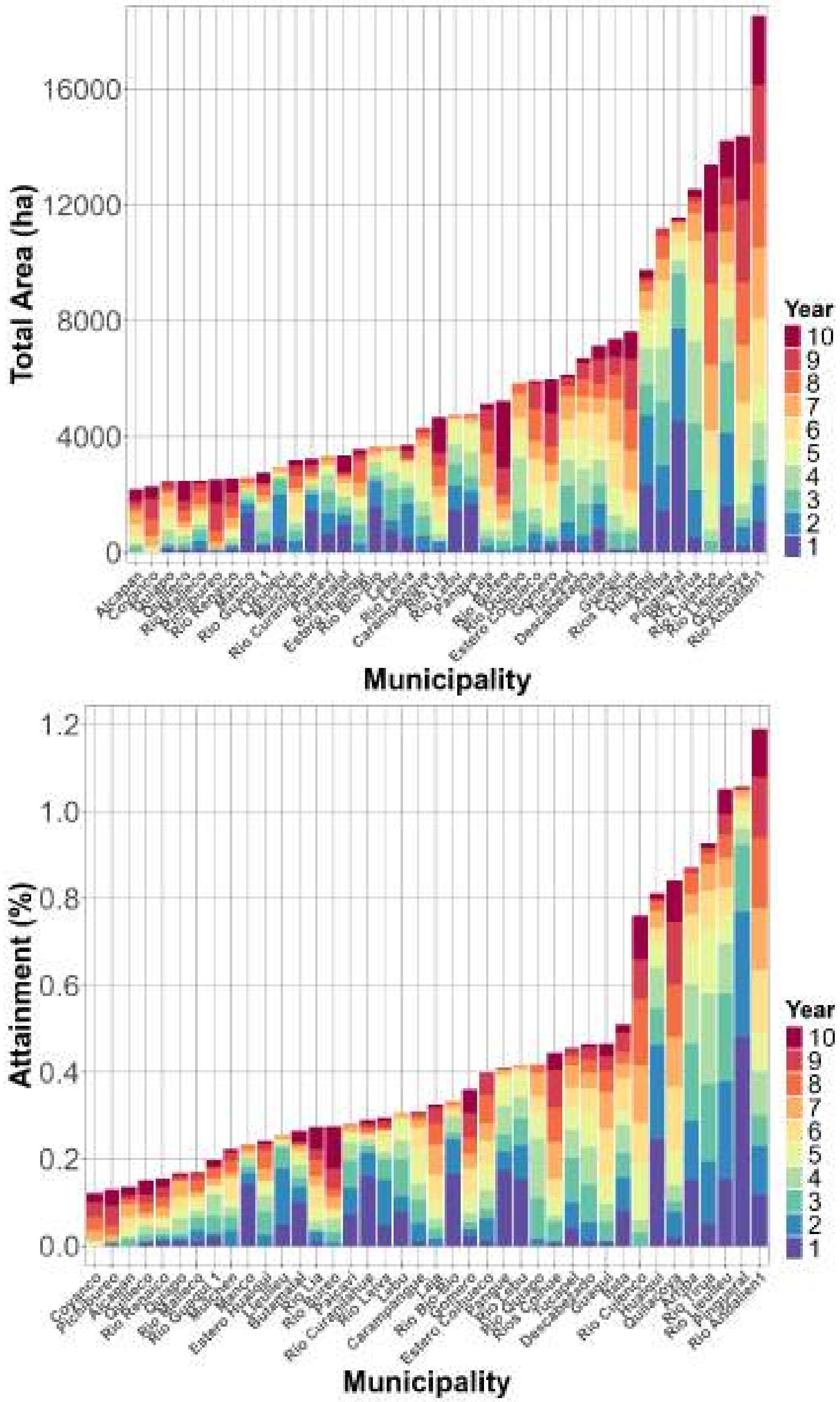

Figure 161 Top: area treated in ha for each Municipality by implementation year. Bottom: main prioritized objective attainment (%) for each Municipality by implementation year.

In Figure 162 we present all stands that met either more than two (orange) and three (red) objectives, but we do not suggest that spatial optimization allocation since the six out of eight objectives achieved very low attainments. There are about 200k ha of stands that meet at least two of the three main objectives examined above (community exposure sources, downstream protected value and ignition probability), and 70k ha of stands that meet all three objectives (Figure 163). For the analysis, these stands are not grouped in projects. When we start selecting these stands that were part of the ForSys solutions for the three main objectives based on the best available stands for the objective of community exposure sources, we notice that by treating approximately 50k ha we can achieve a 14.5% for that objective, ~5% for the downstream protected values & the protected areas exposure sources, and 4% for the ignition probability, burn probability and wildfire hazard (Figure 163-left). By selecting with the same way, the stands that meet all three criteria, an attainment of community exposure sources of ~8% is achieved if we treat 20k ha, achieving a ~3% attainment for the downstream protected value and 2% for the ignition probability (Figure 163-right). By treating the same amount of area (~20k ha), we achieve larger attainments in the relevant optimization runs, i.e., 8% vs. 10% for community exposure sources, 3% vs. 7% for the downstream protected value, and 2% vs. 2.8% for the ignition probability.

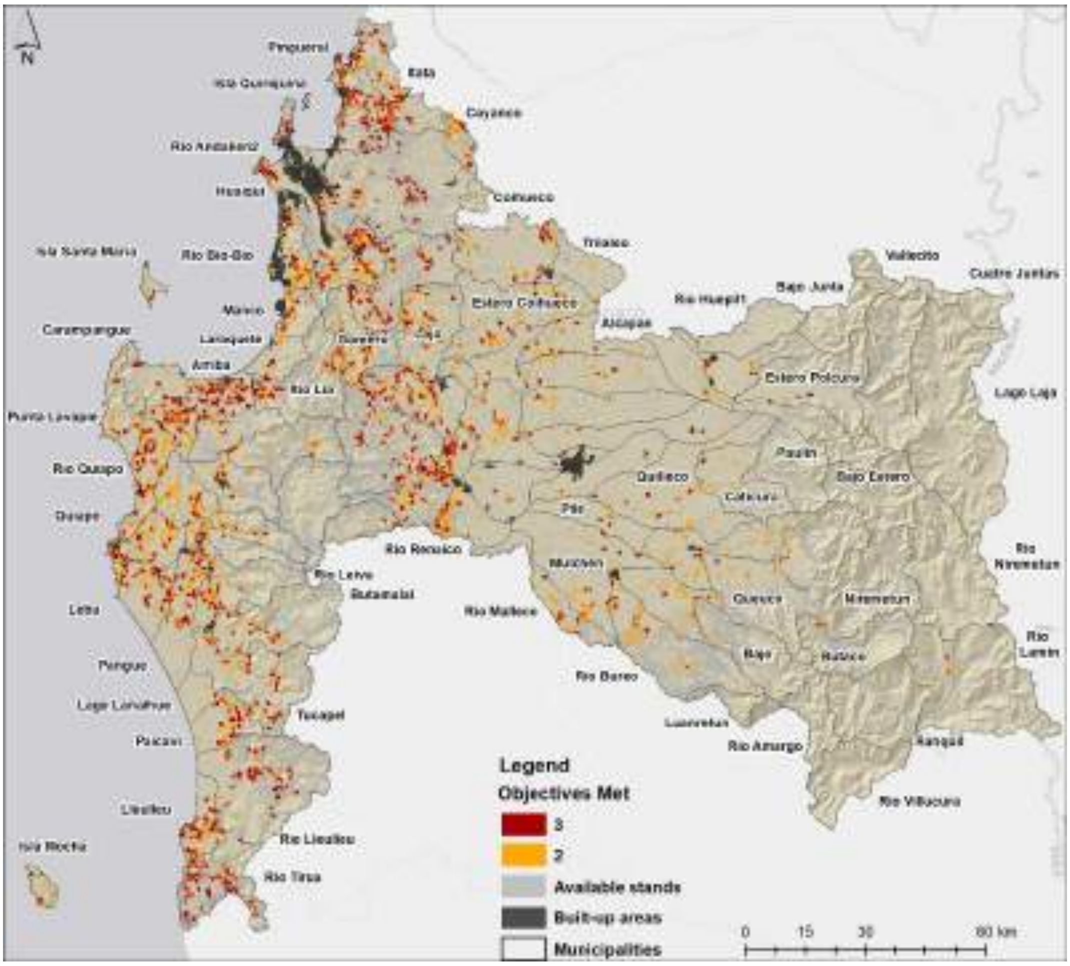

Figure 162 Allocation of stands that were selected from the three runs of SET1 that meet two or more objectives (orange) and three objectives (red).

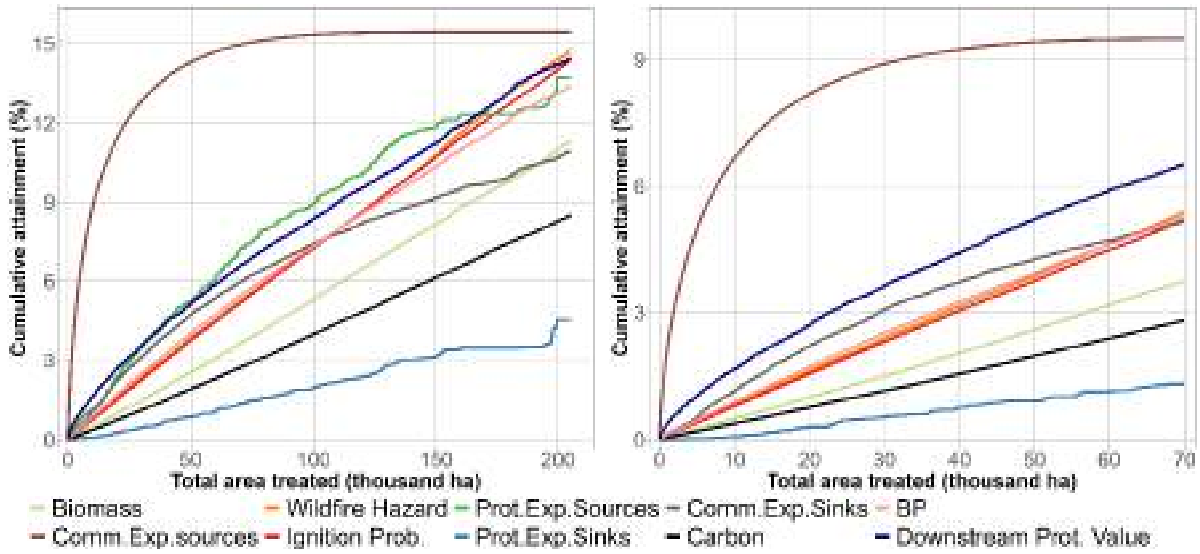

Figure 163 The attainment of the eight objectives analysed for the stands that were selected from the three runs of SET1 that a) meet two or more objectives (left) and b) meet three objectives (right). For graphing purposes, the stands selected first had the highest performance for the objective of community exposure sources.

4.5.3 SET2: Equity among planning areas

In this set of runs we chose to apply an equity approach among the different Municipalities, meaning that we requested the same number of projects for each Municipality with the same treated area. This set does not offer a 10-year management plan. ForSys, given that there are enough available stands, will return what was requested regardless of the area of each Municipality (a Municipality with 50k ha can potentially receive the same projects and area treated as one with 10k ha area). In Figure 164 the attainment curve of community exposure sources can achieve up to ~20% when all the solution area is treated (173,500 ha), with downstream protected value achieving a roughly ~12% attainment, along with most of the other objectives (wildfires hazard, burn probability, ignition probability, protected areas exposure sources and community exposure sinks). Biomass and Carbon are correlated but do not achieve the same level of attainment (9% and 6.5%, respectively), with the smaller attainment achieved for the protected areas exposure sink (~3%).

In Figure 165 we mapped the 50 projects of each Municipality, with warmer colours applied to the best performing projects when prioritized for the objective of community exposure sources.

The Municipality with the highest attainment for the main objective (community exposure sources) is Pangue with 1%, followed by Rio Tirua and Estero Coihueco (~0.8%), Rio Andalien1 (0.6%) and Coihueco (0.55%) with the remaining Municipalities achieving < 0.5% attainment (Figure 166). Except for the objective of protected areas, where we notice that some Municipalities are performing highly although not doing well with the main objective (Rio Bio-Bio, Tucapel & Hualqui), all other management objectives achieved low attainment that is <0.5% for all Municipalities.

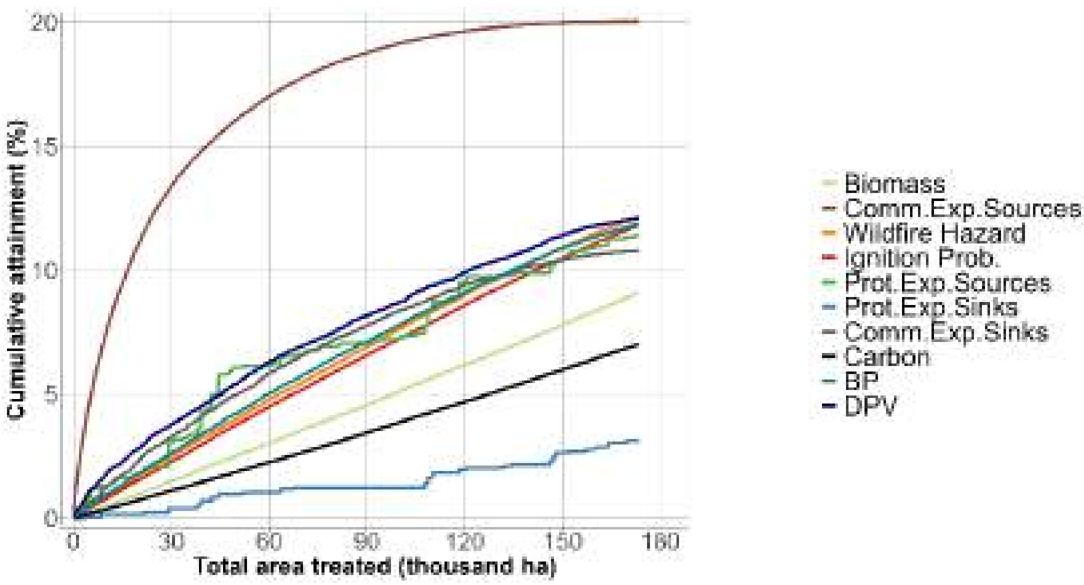

Figure 164 Area treated for all Municipalities and the level of attainment for all objectives after prioritizing for the objective to reduce the exposure of developed areas from incoming wildfires (exposure sources).

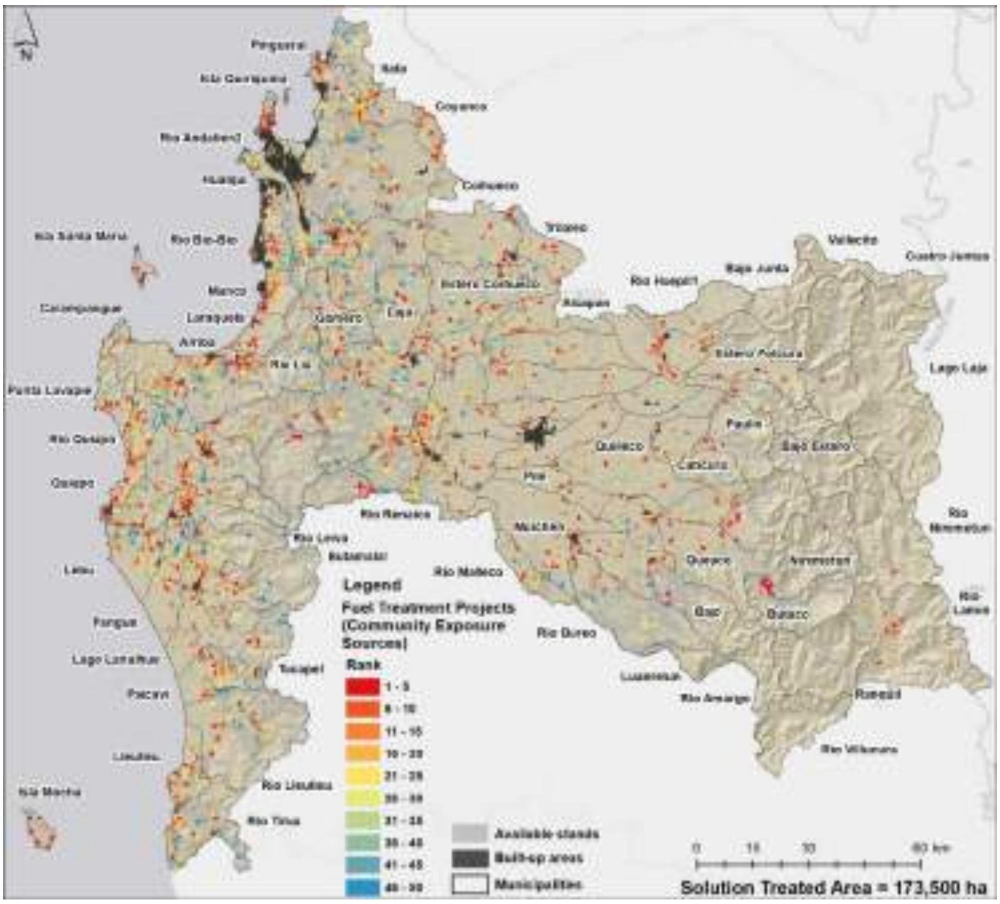

Figure 165 Map of the 50 best projects of each Municipality, ranked by the level of attainment they achieve, with the objective to reduce the exposure of developed areas from incoming wildfires (exposure sources).

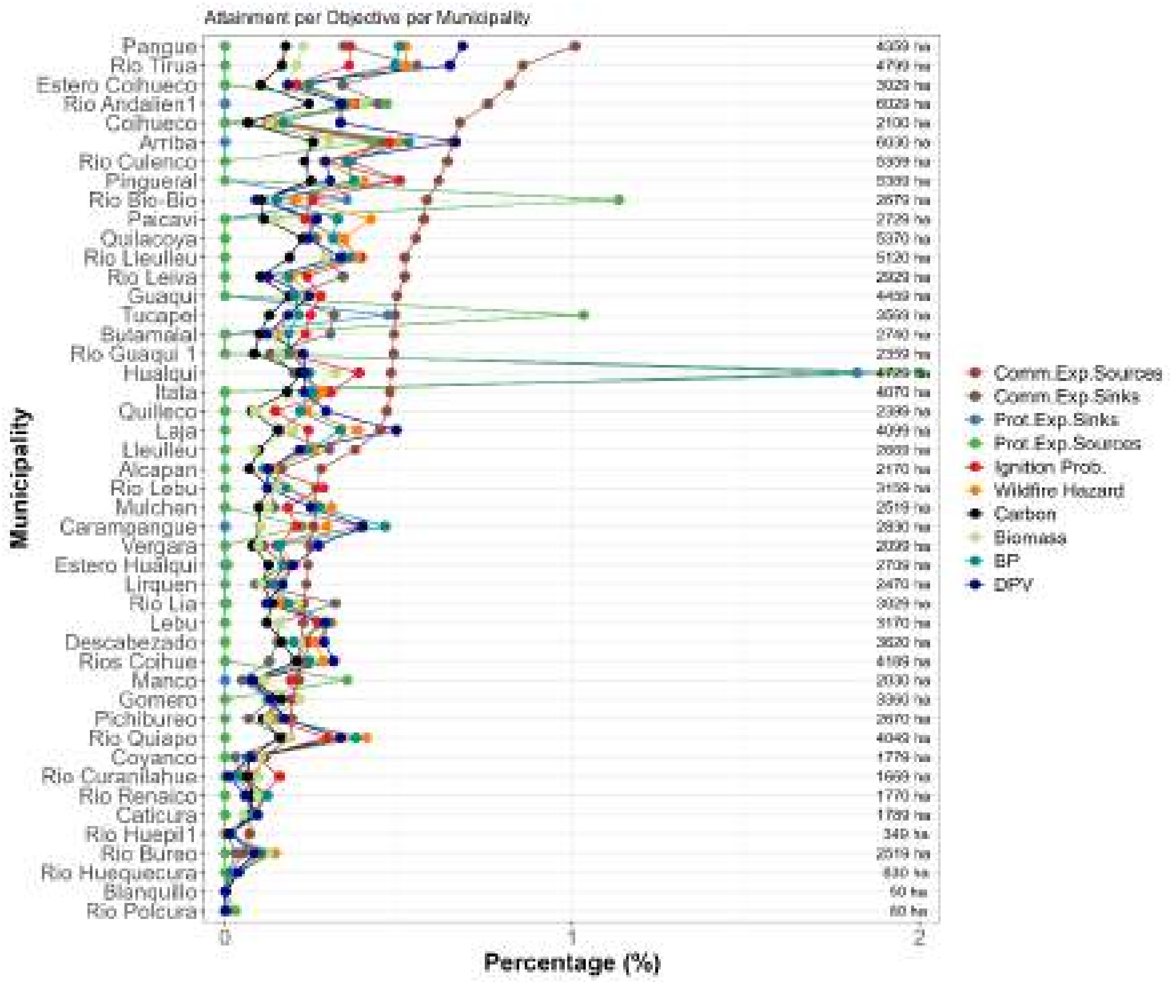

Figure 166 Attainment for each Municipality for the ten objectives when prioritized to reduce the exposure of developed areas from incoming wildfires (exposure sources).

The second run for this set prioritized fuel treatments for the management objective of limiting the exposure from the areas with high downstream protected value. In Figure 167 the attainment curve of the main objective can achieve up to ~17% when all the solution area is treated (236,100 ha), with community exposure sources and ignition probability achieving a roughly ~15% attainment, while wildfire hazard reached 16% and burn probability 14%. All the other management objectives achieved attainments between 5% (protected areas exposure sinks) and 12% (biomass and protected areas exposure sources). In Figure 168 we mapped the 50 projects of each Municipality, with warmer colours applied to the best performing projects when prioritized for the objective of community exposure sources. Many Municipalities received less than 50 projects, especially those at the eastern parts over the mountainous areas.

In Figure 169, the Municipality of Rio Tirua achieved the highest attainment (1.1%) by treating 5k ha, followed by Arriba (1%) with 6.4k ha, Pangue (0.8%) with 4.7k ha, Rio Andalien1 (0.6%) with 6.2k ha), Carampangue and Laja (~0.5%) with 3.4k ha and 4.5k ha, respectively. All other Municipalities achieved attainments <0.5%. It is notable that for the Municipalities of Hualqui, Tucapel and Rio Bio-Bio, the objectives of protected areas exposure sources & sinks performed better than the main objective.

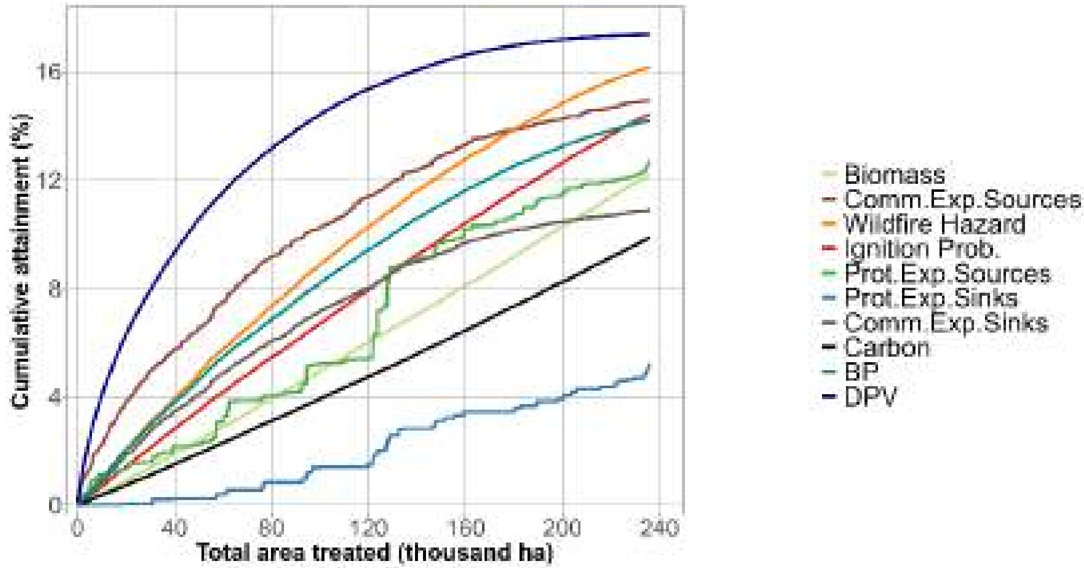

Figure 167 Area treated for all Municipalities and the level of attainment for all objectives after prioritizing for the objective to reduce the exposure of protected areas from incoming wildfires (exposure sources).

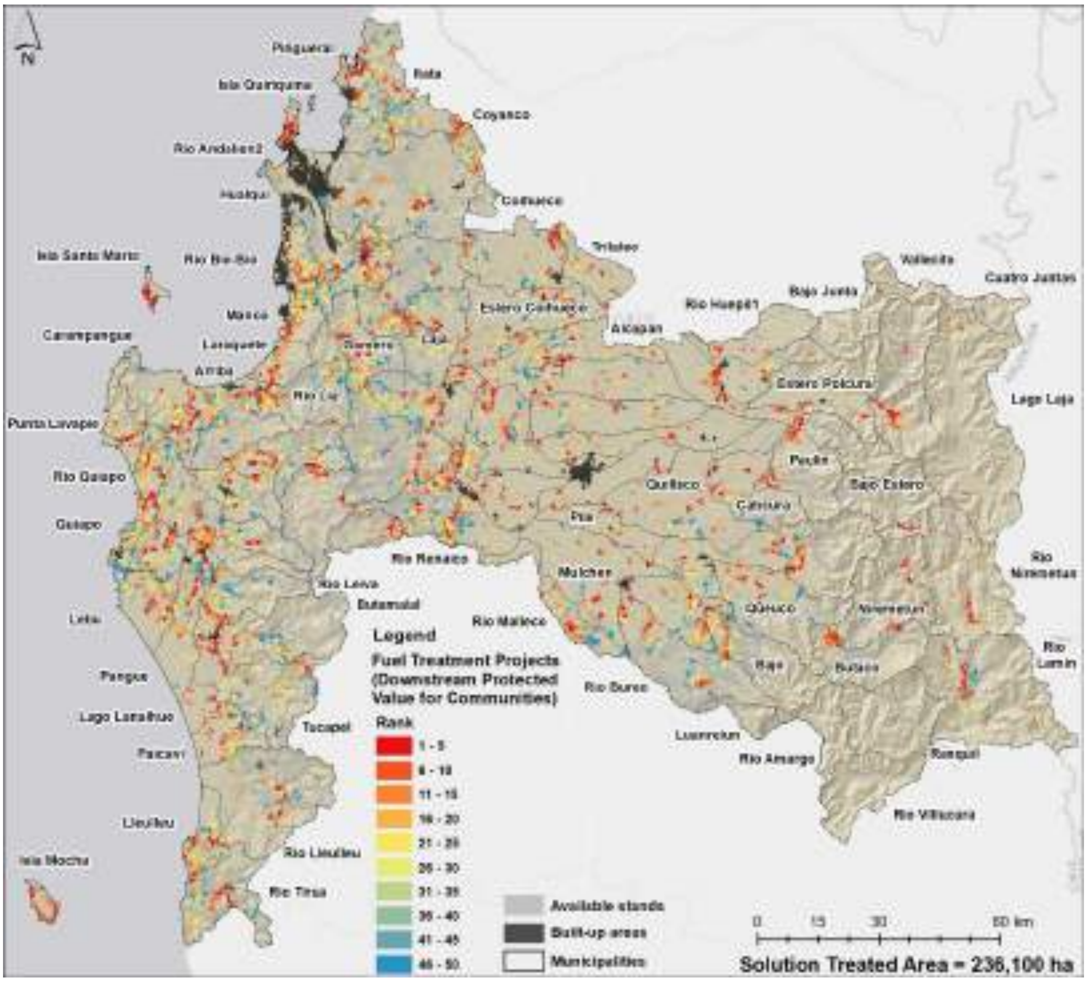

Figure 168 Map of the 50 best projects of each Municipality, ranked by the level of attainment they achieve, with the objective to reduce the exposure of protected areas from incoming wildfires (exposure sources).

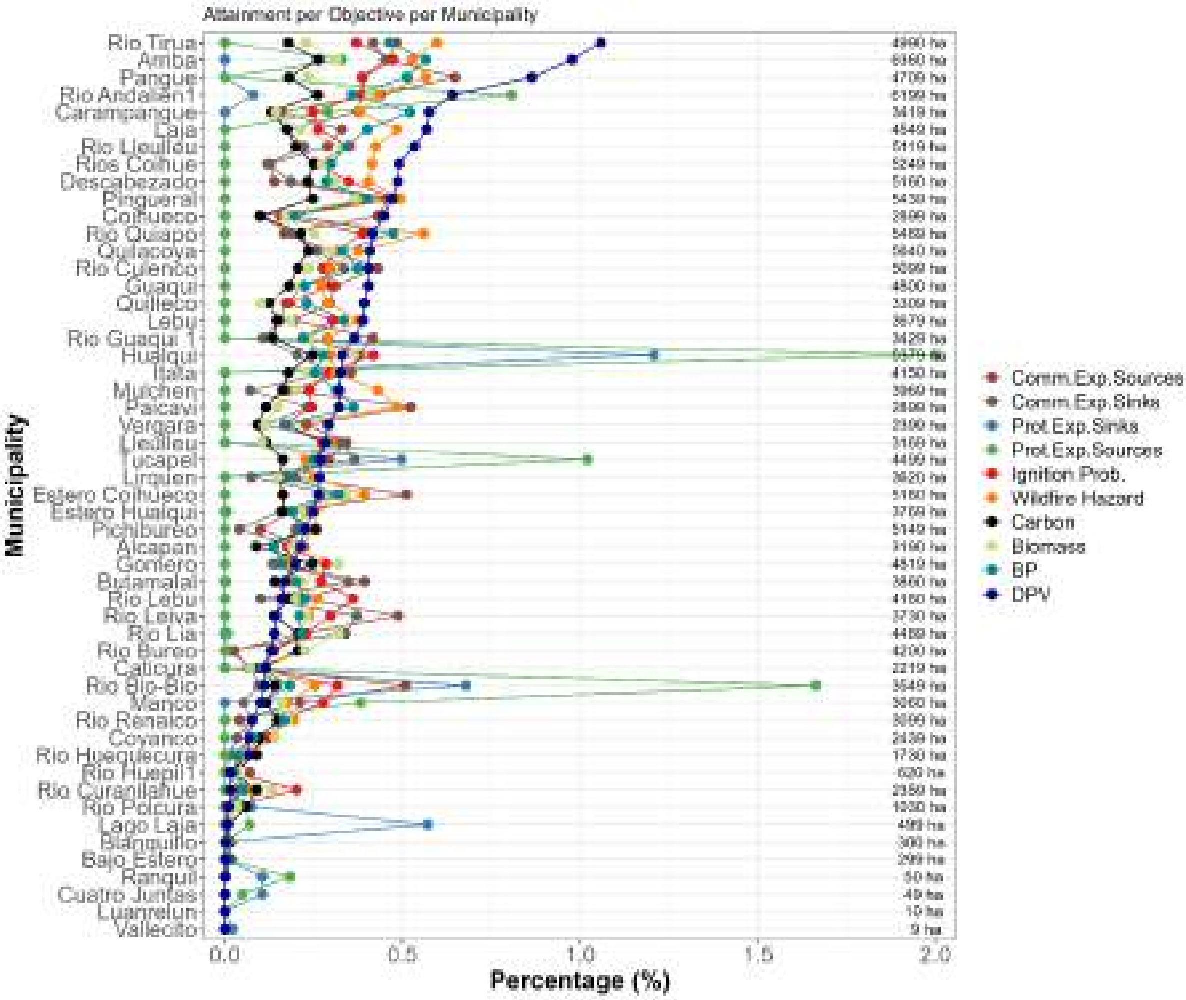

Figure 169 Attainment for each Municipality for the ten objectives when prioritized to reduce the exposure of protected areas from incoming wildfires (exposure sources).

The final run for this set prioritized fuel treatments for the management objective of limiting the ignition probability. In Figure 170 the attainment curve of the main objective (red line), although when starting and up to 10k ha is the best performing, as the treated area increases and up to ~120k ha is second in terms of attainment and behind the protected areas exposure sources, to end up achieving ~16.5% when all the solution area is treated (250,000 ha) and be the first ranked objective. It is followed by wildfire hazard (16%), burn probability, protected areas exposure sources and community exposure sources with 14%, biomass and downstream protected value with 13%, community exposure sinks (11%), carbon (~10.5%), and protected areas exposure sinks (~6%). In Figure 171 we can notice a good distribution of projects across the landscape, since all of the available stands had an ignition probability value greater than zero, so, there were plenty to select and build the projects. Finally, in Figure 172 the range of performance among the Municipalities is low, with the highest performing (Pingueral) achieving a 0.5% attainment after treating ~5k ha. The treated area among the districts was quite similar and approximately at 4,500 ha. Some Municipalities like Hualqui, Rio Andalien1, Rio Bio-Bio and Tucapel achieved high attainment for protected areas exposure sources (>1%), higher than the attainment of the highest performing Municipality for the main objective.

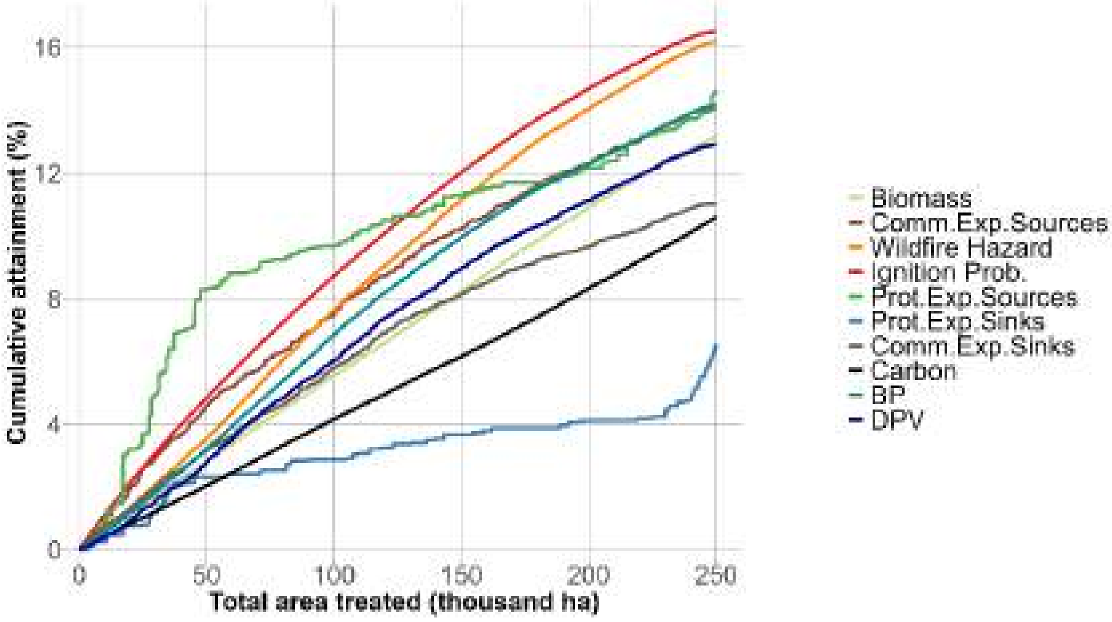

Figure 170 Area treated for all Municipalities and the level of attainment for all objectives after prioritizing for the objective to reduce new ignitions by treating in areas with high ignition probability.

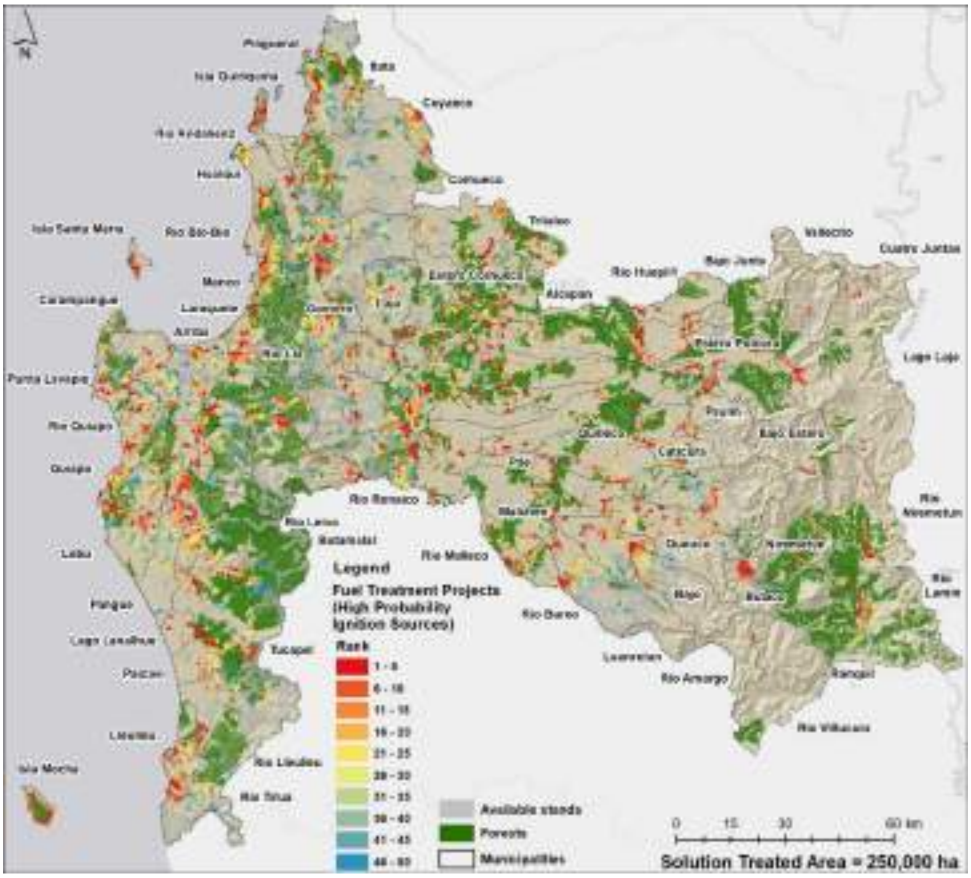

Figure 171 Map of the 50 best projects of each Municipality, ranked by the level of attainment they achieve, with the objective to reduce new ignitions by treating in areas with high ignition probability.

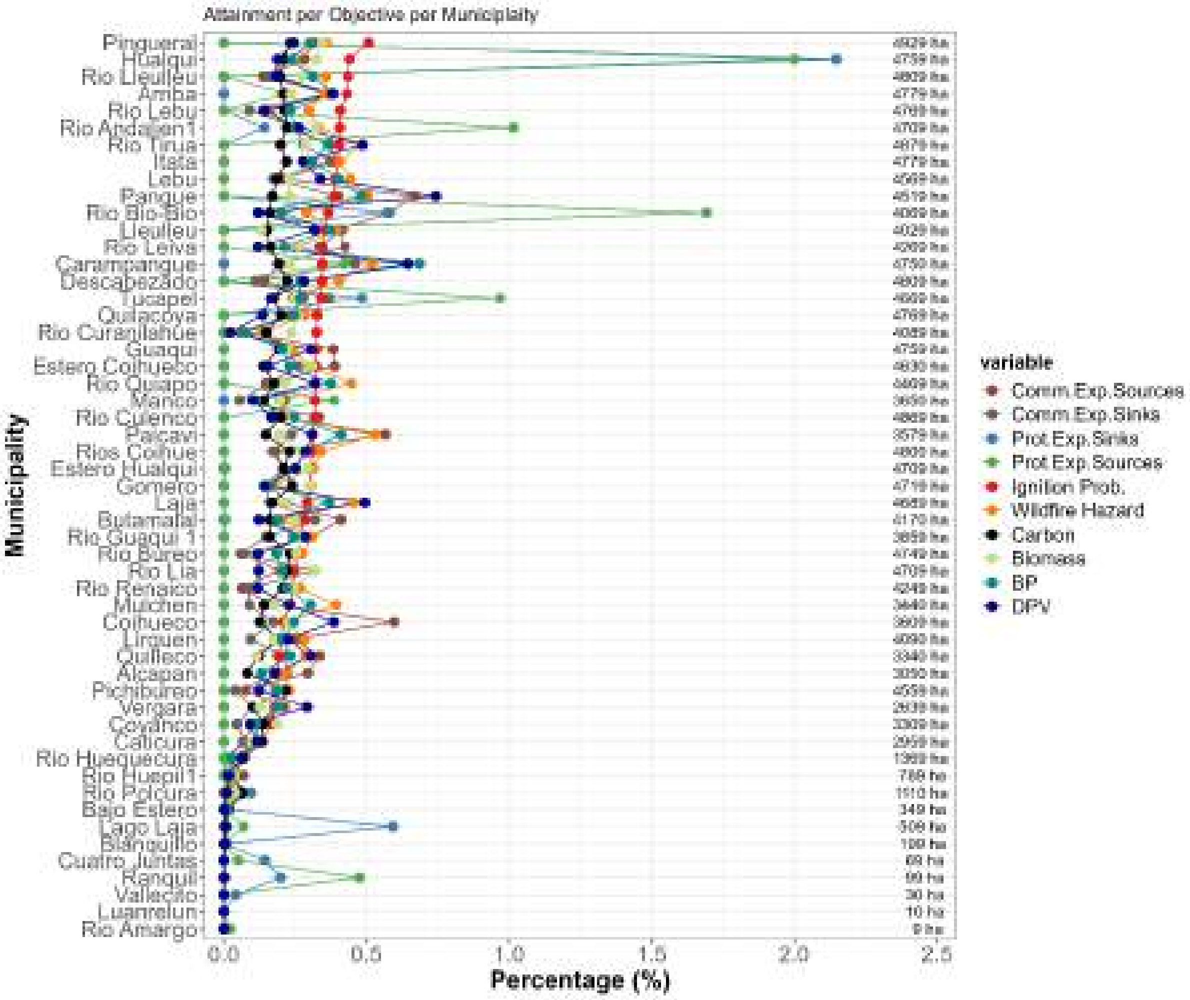

Figure 172 Attainment for each Municipality for the ten objectives when prioritized to reduce new ignitions by treated in areas with high ignition probability.

There are about 220k ha of stands that meet at least two of the three main objectives examined above (community exposure sources, downstream protected value and ignition probability), and 90k ha of stands that meet all three objectives (Figure 173). When we start selecting these stands based on the best available stands for the objective of community exposure sources, we notice that by treating 40k ha we can achieve a ~16% for that objective, ~5% for the downstream protected value, and approximately 3% for the ignition probability (Figure 173-left). By selecting with the same way, the stands that meet all three criteria, an attainment of community exposure sources of ~10% is achieved if we treat 30k ha, achieving a ~4% attainment for the downstream protected value and <2.5% for the ignition probability (Figure 173-right). By treating the same amount of area (~30k ha), we achieve larger attainments in the relevant optimization runs, i.e., 10% vs. 12% for community exposure sources, 4% vs. 9% for the downstream protected value, but quite similar values, i.e., 2.5% vs. 3%, for the ignition probability. In Figure 174 we present all stands that met either more than two (orange) and three (red) objectives.

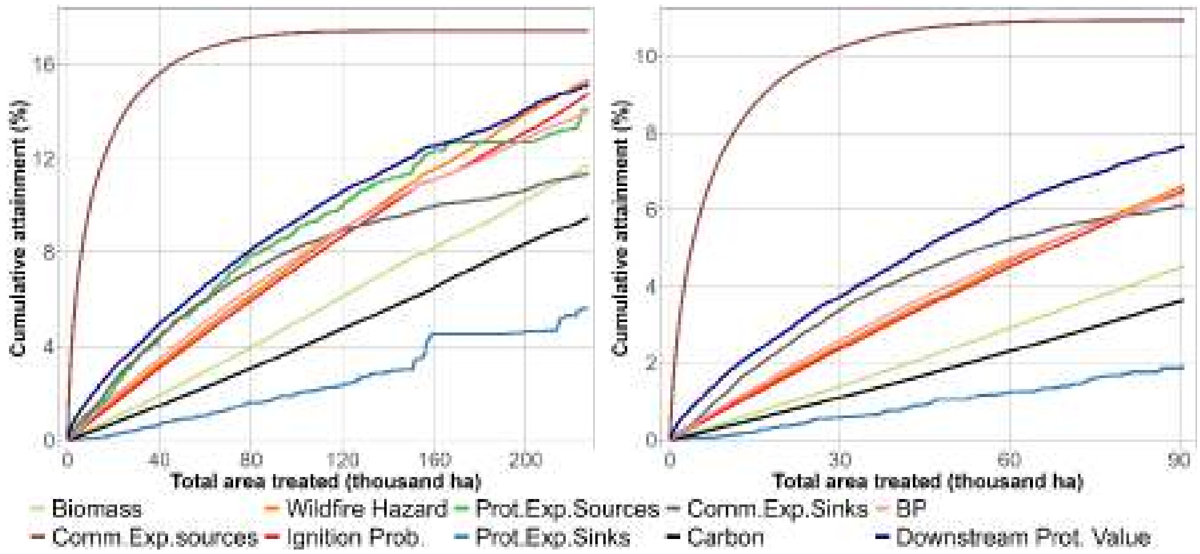

Figure 173 The attainment of the eight objectives analysed for the stands that were selected from the three runs of SET2 that a) meet two or more objectives (left) and b) meet three objectives (right). For graphing purposes, the stands selected first had the highest performance for the objective of community exposure sources.

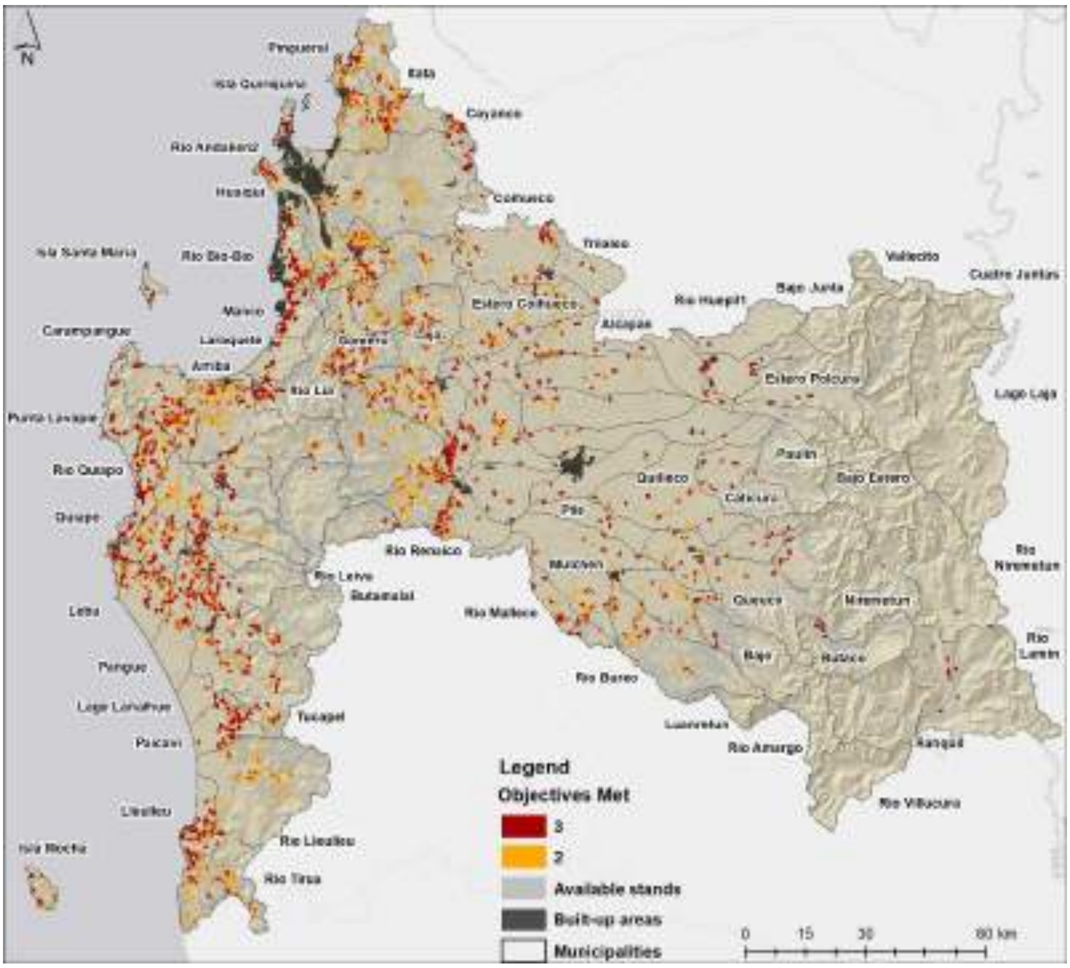

Figure 174 Allocation of stands that were selected from the three runs of SET2 that meet two or more objectives (orange) and three objectives (red).

4.5.4 SET3: Trade-offs and joint optimality

This set of runs revealed the potential existence of trade-offs between different couples of management objectives and mapped the joint optimality on the spatial allocation of projects across each managing landscape. We note here that a couple of objectives do not necessarily mean the existence of trade-offs. These trade-offs were examined at the scale of Municipalities. In addition, although some Municipalities might show strong trade-offs, others might have none. The first couple examined the community exposure sources vs. the downstream protected value. The map in Figure 175 shows a solution of approximately 117,500 ha for the three examined weight combinations (equal, 10-3 and 3-10) and creates a maximum difference of 2.4% in the attainment of the community exposure sources, and 0.4% for the downstream protected value. Blue- and orange-coloured projects that overlap with the equal weighing scheme are not visible, and they only appear where these projects were not selected by the other two weighting schemes.

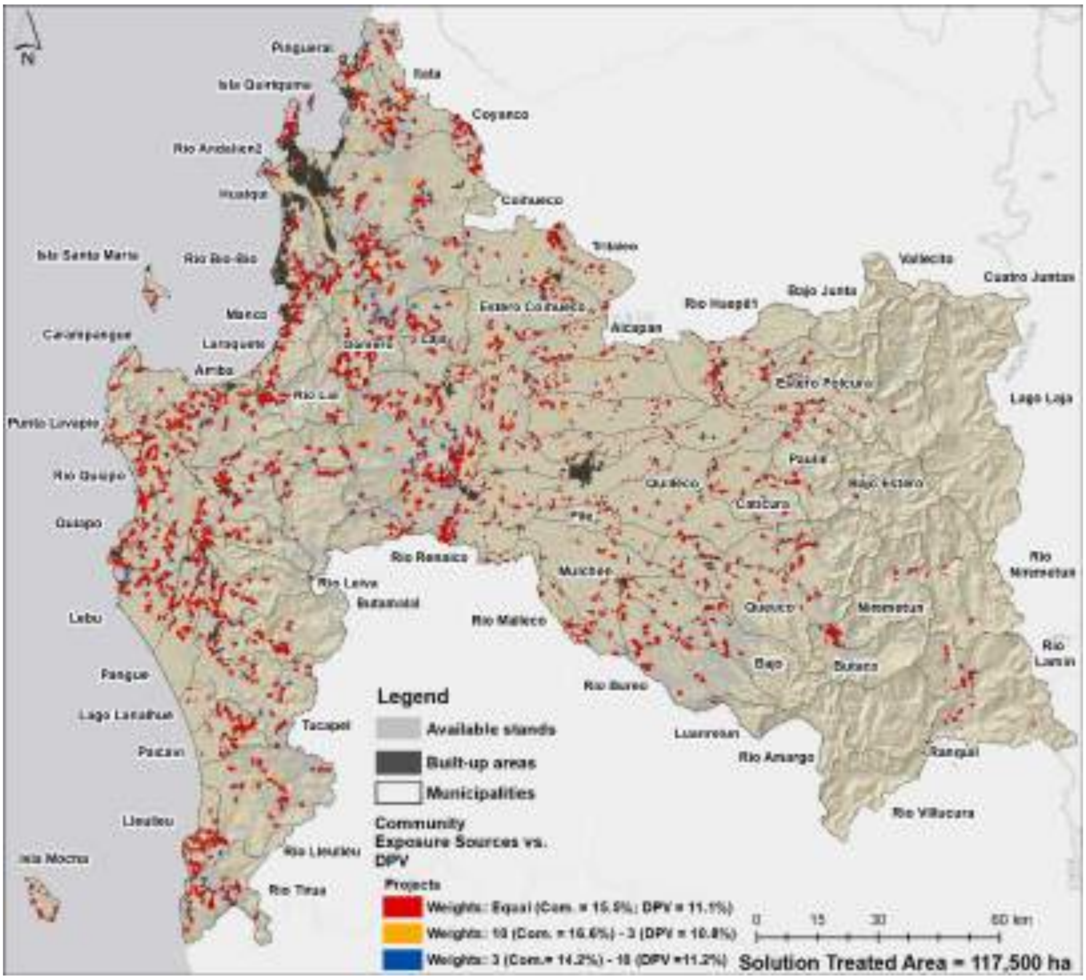

Figure 175 Trade-off scenario planning runs with three weighting schemes: a) equal weights (red); b) Developed areas exposure sources objective weight maximized (10) and downstream protected values for developed areas set to low (3) (orange); c) Downstream protected values for developed areas objective weight maximized (10) and developed areas exposure sources set to low (3) (blue). Blue- and orange-coloured projects that overlap with the equal weighing scheme are not visible, and they only appear where these projects were not selected by the other two weighting schemes.