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Final Report

FarmReal

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Executive Summary

Fuel treatments aimed at reducing both horizontal and vertical continuity in fuels are of paramount importance as a prevention measure against fire propagation. Possible techniques include pruning, thinning (mainly low thinning), mastication, prescribed burning, and prescribed (or targeted) grazing. Their main target is crown fire avoidance by treating surface fuels and promoting low density and vertically discontinuous stands, thus eliminating fuel ladders. Grazing is an effective, nearly carbon-neutral weed control technique which is cost-effective, nontoxic, and nonpolluting. Goat grazing is a very interesting solution: if confined by a metallic or electrified fence within a restricted pen, with a rather high density, goats browse the available foliage and twigs from all woody plants as well as all herbaceous vegetation. The FarmReal project's main objective is to contribute to the conservation of a traditional activity (almost extinct in Europe), of enormous importance for the economy of rural areas. Developing a disruptive concept of community herd, which is governed by a profitable and sustainable business model, it will take advantage of the latest communication and electronic technologies.

The project consists of a platform that allows registered users to adopt and monitor the daily lives of goats. Thus, the FarmReal user, in addition to the social added value of adopting an animal to help with its sustainability, also benefits from a recreational component, in which he can observe the animal remotely, know its location, access data on its productivity and behaviors, physically visiting the space and carrying out activities with the animal.

FarmReal is based on smart collar system for livestock, enabling community to monitor .

The first phase of development was guided not only by the innovation in some of the technological solutions implemented, but above all by having occupied the space available for this concept.

It should be noted that in addition to the direct benefit for goat farming in the region, there are also social, cultural and economic benefits for the region:

• from tourism (by the families that adopt the animals, by curiosity and by the innovation implemented in the region);

• cultural activities organized (specialized training for goat farming professionals; workshops and workshops for visitors, for example: how to make cheese, be a shepherd for a day, among others);

• and dynamization of means of dissemination of endogenous products (promoted either on the FarmReal web platform or in activities developed locally).

In short, we believe that this initiative will unequivocally improve the quality of life of the inhabitants of this rural area.

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Context

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Goat grazing as a wildfire prevention tool

Introduction

The general response of most countries to the problem of an increasing number of fires and burned areas has generally been to strengthen fire suppression capacity (Costa Alcubierre et al. 2011). France, Greece, Italy, Spain and Portugal spend a total of 2500 million Euros annually in the fight against forest fires, 60% of which allocated to cover costs related to suppressing fires, while only 40% is invested in activities targeted to prevention (EFIMED 2012). Despite the high investment to improve fire suppression resources, mainly through expenditure on important aerial fleets, such as in Spain, Greece or Italy, the phenomenon continues to be characterized by an aggressive trend, with a progressively reduced interval between dramatic years. Wildfires occurring during prolonged and severe heat waves (such as in 2003 and 2005 for Portugal, 2006 for Spain, 2007 for Algeria, Italy, Spain and Portugal, 2010 for Russia, 2012 for all the Mediterranean countries including Algeria) demonstrate that a different approach must be considered for tackling the problem of forest fires. This means a shift from the short term policy, which is mainly based on huge investments for suppression measures, to a long term preventive policy (Birot 2009, Montiel & Herrero 2010). The key purpose of fire prevention measures is to reduce the number of fires through hazard reduction, education, and law enforcement. Improving prevention strategies seems mandatory if a further reduction in the mean yearly burnt area is to be pursued (Ruiz-Mirazo 2011).

Fuel treatment and wildfire minimization

An appropriate approach to wildfire prevention must be aimed at both lessening the possibility of a fire occurring and minimizing its spread should one occur. This can be achieved through fuel treatments for biomass reduction, which are paramount to wildfire abatement (Omi & Martinson 2002). To reduce fire damages, an infrastructure of roads and water supply should be constructed, firebreaks and fire detection systems established, an immediate and efficient intervention of ground crews ensured, but above all, fuel treatments should be timely executed (Leone et al. 2000). Fuel treatments are a key factor to decreasing wildfire risk (Omi & Joyce 2003): they target different fuel components in order to achieve both forest structures and fuel characteristics which are able to reduce the likelihood of fire spread. Fuel treatments are mainly aimed at eliminating the vertical and horizontal continuity of fuels, in order to disrupt the vertical progression of fire (passage from surface fuels to ladder fuels to canopy fuels), and its horizontal progression, especially from crown to crown (Scott & Reinhardt 2001, Graham et al. 2004). Activities aimed at reducing surface fuels (low vegetation, woody fuel, shrub layer) decrease the chances of surface fires igniting ladder fuels and canopy fuels (Pollet & Omi 2002, Fernandes & Botelho 2003). The range of possible treatments to modify forest fuels is rather wide, varying from pruning (Leone 2002) to thinning, to mechanical thinning, to fuel mastication (Harrington 2012) to prescribed fire (Leone et al. 1999, Fernandes & Botelho 2003, Molina et al. 2010, Rego & Montiel 2010, Ascoli et al. 2012) to grazing (Hart 2001, Ruiz-Mirazo et al. 2009, Ruiz-Mirazo 2011, Mancilla-Leytón & Martín Vicente 2012). As an alternative to some techniques, a few of which are often perceived as aggressive according to public opinion - such as prescribed fire (Knapp et al. 2009, Vélez 2010) or herbicides - the use of grazing animals could be an efficient method for controlling shrub encroachment and reducing the risk of fire through the elimination of dangerous fuel ladders, as represented by the continuity of grasses and shrubs which enable rapid fire propagation and which permit the transition from high intensity running fires to crown fires (Pollet & Omi 2002, Fernandes & Botelho 2003). All these practices can collectively be targeted as “preventive silviculture”; their main target is crown fire avoidance by treating surface fuels and promoting low density and vertically discontinuous stands (Omi & Joyce 2003); this also helps to modify fire behavior sufficiently so that some wildfires can be more easily suppressed (Graham et al. 2004). Preventive silviculture manages Mediterranean forests by enhancing their capacity to protect themselves from fires by “creating discontinuities, avoiding very extensive, monospecific surface areas and creating a patchwork of different inflammability levels that disturb the fire” (Vélez 1990). The purpose of this article is to emphasize the importance and the role of grazing, mainly by goats, as a prevention tool against wildfires. Goats can help to mitigate the devastation caused by wildfires by consuming fuels with their specific grazing/browsing habits and thus reducing horizontal and vertical continuity of fuels.

Grazing problems

In the Mediterranean countries grazing has generally been perceived as negative due to experiences of frequent overgrazing and the use of fire for pasture renewal, both of which can cause the onset of desertification. The combination of wildfires and overgrazing is the main cause of rangeland degradation and desertification in Mediterranean European and in most M.E.N.A. (Middle East and North Africa) countries. On the contrary, if properly managed, grazing can play a positive role in fire prevention while preserving species diversity through the replication of the ecological effects of the wild relatives of livestock (Mancilla-Leytón & Martín Vicente 2012); for this reason it is less likely to elicit a negative public response than the use of prescribed burning, herbicides or thinning. Grazing is probably the most ecologically sound technique for creating discontinuities in fuels, mainly at the shrubby layer, and disrupting fuel ladders. For this reason it is officially considered as a wildfire prevention tool in many countries such as Italy (article 3 of Law 47/1975, now repealed; many regional laws also include grazing by cattle, sheep and pig as appropriate preventive measures). As a matter-of-fact, until relatively recent times grazing by domestic animals was considered among the major causes of the destruction of the Mediterranean forests, with goats being singled out for their predilection for woody forage (Dimanche & Coudour 2005). Fuel reduction via prescribed herbivory has now become an acceptable and generalized tool, although as little as 15 to 20 years ago the use of livestock was not officially considered an appropriate tool for fuel reduction (e.g., Pittroff et al. 2006 for California). The goat is the most suitable species for this purpose because of its browsing ability. On the other hand, in the Mediterranean countries the goat has always been considered a detrimental species, negatively called the “razor of the globe” by Cavara (1914) who coined this image to indicate that goats are destroyers of forests, since they can easily climb young trees and eat all the leaves from branches, or eat all the leaves off seedlings. A similar image of the “razor of the forests” was adopted by von Mayddel (1980a, 1980b) who considered goats responsible for damage and degradation of established plants as well as for the destruction of regeneration (Moser 2006). In the early XIX century some European authors (Beatson 1810, Guatieri 1816) provided their own so-called evidence of the negative role of goats, and even accused them of producing environmental catastrophes and evil consequences. This popular assumption has been very hard to dispel (Messines 1952, Seigue 1985, Cans 1999). The controversy surrounding the goat is associated with several interactions with the environment and alleged resource degradation (Fig. 1). Such criticisms are not unique, and can apply to other herbivores, but with goats the allegations are more severe because of their unique mouth parts, selection of feeds, ability to adapt to varying forage quality, their capacity to use coarse grazing and shrubs to their advantage (Devendra 1999) and their ability to use forage resources that cannot be utilized by other ungulates such as sheep or cattle (Nastis 1997). It is often argued that grazing, with goats as the main catastrophic agents, has been a major contributor to deforestation, perhaps even more so than agricultural clearances (Papanastasis 1986, 2004, Harris 2007, 2012). More likely, because goats are often among the last species able to feed on poor range condition, they are frequently blamed for the damage done by many decades of abuse by other classes of livestock (Green & Newell 1982, Papanastasis 2000). The damaging effect of overgrazing may actually be evident in forests with relatively closed crowns and lack of understorey shrubby vegetation, where goats are forced to browse tree seedlings, young trees or branches of the older trees, thus preventing the regeneration of the forest while at the same time trampling the forest floor and its soil (Papanastasis 1986, Lipson et al. 2011). Environmental degradation is also associated with the ownership of goats by landless pastoralists and transhumant who live in poverty and are able to survive only because of the goats. Such situations are not uncommon, especially in the more marginal areas of Asia (e.g., Pakistan, India and China), Africa (e.g., Tanzania and Sudan) and Latin America (e.g., Mexico and Peru - Devendra 1999). Only in recent times has it been realized that goats are not the real culprits but the continuous, uncontrolled overgrazing for which humans are responsible. A threat to forests comes therefore from irrational and uncontrolled goat grazing (Devendra 1999): it is the mismanagement of goats, rather than their mere presence, that has resulted in damage to Mediterranean forests in the past (Papanastasis 1986, 2004, Siddle 2009).

Goat feeding habits

Goats exhibit very peculiar feeding habits: their nimble lips and very prehensile tongue permits them to graze on very short grass and to browse on foliage not normally eaten by other domestic livestock, which all combines in an excellent nutrient conversion efficiency for the production of milk (about 45% - Hart 2001, Georgoudis et al. 2005). Goats are facultative browsers; they prefer to feed at eye level and upward and then feed on forage from the top of the plant down (Hagstrom et al. 1993, Hutchens 2003). They move freely from plant to plant, removing foliage from select portions of plants. Foliage meals are dictated by quality factors that ensure adequate protein and energy levels. Unlike larger ruminants, there is little fouling or treading of forage (Hutchens 2003). Goats are often considered to prefer feeding more on shrubs than on grass; they really take a wider variety of plants than other classes of livestock but selectively feed if there is a choice (Green & Newell 1982, Walker 1994). Goats feed on a variety of shrubs, some of which are useless for other domestic species, exhibiting a relevant capacity for transforming otherwise useless crude fiber into noble proteins; they are therefore the best adapted species for the consumption of all Mediterranean shrubs (Green & Newell 1982), providing for an exception of those with high aromatic oil content which are less palatable (Rosmarinus officinalis, Lavandula stoechas, etc. - Mancilla-Leytón & Martín Vicente 2012). Because of their unusual preferences for the leaves and terminal twigs of woody plants, goats have been exploited as an alternative to herbicides and mechanical cutting against encroaching herbaceous weed and brush species, provided the targeted plants are palatable. Thanks to their inquisitive nature and tolerance of high tannin material, goats may eat unpalatable weeds and wild shrubs that may be poisonous, but they are often not affected by poisonous compounds or anti-nutritional factors if a sufficient number of other plant species are available. Because goats prefer to consume a very varied diet, the detrimental effects of poisonous compounds found in certain plants can be diluted (Luginbuhl 2000). The propensity of goats to stretch upwards on their hind legs allows them to commonly browse up to a height of 2 meters in areas where trees and hanging vines are present (Lu 1988). Reports that browsing goats are able to reduce tree growth and slow down woodland expansion in aspen stands, until individuals reach an escape size of 1.5 m in height (Ascoli et al. 2013), is confirmed by the findings of other authors (Du Plessis et al. 2004 for eastern Cap Region in South Africa, Foroughbakhch et al. 2013 for Mexico). The types of vegetation present influence the foraging position or posture of goats, most notably the use of a bipedal stance and aerial positions. Goats will only use a bipedal stance if trees are present and will only adopt aerial foraging positions if the trees present are climbable (Goetsch et al. 2009). Here stays the goat's main role in wildfire prevention, as they easily consume grasses or forbs before they are classified as the 1h and 10h time-lag (a fuel's time-lag is proportional to its diameter and is loosely defined as the time it takes a fuel particle to reach 2/3's of its way to equilibrium with its local environment) dead fuel categories described in the literature (Deeming et al. 1972). In other words, goats reduce the availability of dead fuels with a diameter of <2.54 cm and the availability of small live fuels (terminal twigs of woody plants such as shrubs and trees), both of which are the main propagators of fires as components of the lower layer of the fuel ladder. The grazing of goats can impact the amount and arrangement of these fuels by ingestion or trampling (Nader et al. 2007). Grazing at moderate levels has been shown to change wildfire behavior, by slowing its spread, shortening flame length, and reducing fire intensity, although it does not significantly reduce the risk of fire ignition (SRCD 2006). In the vicinity of urbanized areas, grazing can prevent or minimize expansion of shrublands which have much greater fuel loading and pose greater fire hazard than grasslands (SRCD 2006). Grazing can directly reduce the frequency and intensity of fire by removing fine fuels and amplifying the heterogeneity of fuel continuity, and indirectly by causing a shift in plant community composition to less-productive and more-ephemeral species (Fuhlendorf et al. 2008). In Mediterranean areas, where shrubland often prevails, co-grazing with sheep, cattle and horses, which have mainly grazing habits, could greatly improve grazing of grass thus further reducing fuel load. Since goats, cattle, and sheep prefer different forages, in many pasture situations these species do not compete for the same food (Coffey et al. 2004). In some cases, the integration of different treatments represents the best strategy. Livestock cannot effectively control mature brush plants that either grow higher than the animals can effectively graze or which have large diameter limbs. As a solution, underburning and/or cutting can be used to eliminate the large-diameter, 100-hour brush fuels, and grazing can be used as a follow up treatment for controlling resprouting species or shifting the species composition to herbaceous plant fuel material (Nader et al. 2007). The goat has a strong ability to adapt its feeding behavior to the chemical characteristics of food: several studies report selection by goats between diverse plant species, or between individuals of the same plant species according to nutritional quality or the concentration of chemical defenses (Baraza et al. 2009). Under natural conditions, goats range over a large area, grazing and browsing selectively. Under confined conditions, however, goats will become heavy browsers of trees and shrubs, and less discriminating in their grazing habits, due to the reduced supply of available herbage (Haenlein et al. 1992). Goats are not pure browsers: the yearly diet of goats is very variable, as an average about 60 percent shrubs, 30 percent grass and 10 percent forbs (Papanastasis 1986) and almost always contains high proportions of lignified components whenever woody species are presents within the pasture, with a wide range of percentage (62-94% - Nastis 1997). Lopez-Trujillo & Garcia-Elizondo (1995) observed that grasses are selected in a low proportion by goats, even in shrubland reseeded with grass. Papachristou (1997) reported a greater rate of biting by goats when available forage was primarily browse vs. non-browse plant species; Nastis & Nolan (1997) reported that goat diet under different brush cover was mainly based on browsing (53-65.6%) followed by grass (13.1-22%) and forbs (16.5-20.3%).

Goat and fuel break management: first experiments

If confined behind a strong fence, goats browse all the available foliage including all woody plants as well as all herbaceous vegetation (Green & Newell 1982); this is the basis for the use of goats as a brush clearing tool for the construction of firebreaks (Blanchemain 1981, Bonnier 1981, Calabri 1981, Thirgood 1981). In Europe the first experiment of controlled grazing for a brush clearing action dates to the '80s in France, where the Forestry Services of Gard wanted to clear a space to serve as a fire-break. A local goat-breeder proposed to clear the area using his goat herd at a considerably lower price than a traditional land-clearing team. The area was divided into pens of 0.5-1 ha, each enclosed by metal fences. The pens were opened one after another, with a stocking density (number of animals per unit area of land at any one point in time; can be expressed as animal units/ha) of 100-200 animals per ha. The goats were allowed into the pens for only 4-6 hours a day. In six months a firebreak of 100 x 1000 meters was created. The goats ate 2300 kg of edible dry matter per ha out of the available 2900 kg, getting 60-75% of their food requirements by grazing and an increase of up to 10 percent of their live weight per month (Papanastasis 1986). Further experiments were carried out in Languedoc Roussillon region (1985-2005) on a total area of 27 049 ha but the area reduced to a few tens of hectares in 2005 due to budgetary problems (Dimanche & Coudour 2005). In Spain, farmers that take part in wildfire prevention programs make their livestock graze intensively in the fuel break areas defined by Forest Services. In exchange, they receive money and/or in-kind remuneration. In Comunitat Valenciana (eastern Spain), a payment of € 22 ha-1 yr-1 is given to farmers who concentrate their livestock in fuel breaks for a minimum of 130 days. A minimum stocking rate (number of animals per unit area of land over a specified period of time; can be expressed as AUMs/ha - differs from Stocking density by incorporation of time) of one cow, three goats or five sheep per hectare must be maintained; the payment can be increased by some € 20-40 ha-1 yr-1 if water or a fence are necessary (Ruiz-Mirazo & Robles 2012). Similar programs are currently under way in Aragon (3500 hectares of firebreaks) and Andalucía, where the payments per hectare currently range from € 42 to 90, depending on the grazing difficulty (steepness, type of vegetation and distance to animal housing - Ruiz-Mirazo et al. 2009). The reduction of shrubs by grazing goats intensively within the firebreaks is less costly than other alternative treatments; in addition, the presence of goatherd and dogs constitutes a deterrent to arsonists and ensures early detection (Ruiz-Mirazo et al. 2009). We have no knowledge of similar projects in other countries of the EU, where goat grazing for wildfire prevention purposes is still in an experimental phase (Xanthopoulos et al. 2006). On the contrary, in the USA, where goats have been used for vegetation management for over a hundred years (Hart 2001), their use in wildfire prevention has been considered a relative success, since they are environmentally friendly and the most cost-effective, nontoxic, nonpolluting solution available. The use of goats herds is documented in US military camps, such as Camp William (Utah National Guard training field), where no prescribed burning nor herbicides can be employed (Cabrero 2009, Mendenhall 2004), and in the town of Oakland where a budget of 1 750 000 US$ is allocated to wildfire prevention using goats (Voth 2009). Los Angeles, Laguna Beach and the Scripps Ranch community of San Diego have also brought the animals in to clear overgrown areas and assist with wildfire prevention (Burgess 2009). Intensive grazing at the urban interface can create effective firebreaks, as was accomplished near Carson City, Nevada. A fenced corridor around the city was grazed resulting in the removal of 71 to 83% of fine fuels (Taylor 2006). In hills around Menlo Park, Oakland, Los Altos, and Berkeley, California, goats have reduced fuel loads in areas too steep for manual labor or mowers. They remove vegetation without disturbing roots or facilitating erosion (Taylor 2006). More recently, the use of goat grazing is reported throughout other areas of the USA (e.g., Atlanta, Chicago and San Francisco airports; Auburn, CA; Boise, ID; Laguna Beach, CA; Santa Barbara, CA). Goat-powered fuel reduction costs between US$ 400-500 per acre (4046.85 m2 equivalent to about 40% of one hectare), nearly one-third of the cost of more labor-intensive methods of brush clearing (USDA 2013). Domestic livestock grazing (without further details about species) is also a prevention measure officially mentioned within the Catastrophic Wildfire Prevention Act, S.14799, 113th Congress, re-introduced 08.01.2013 by the USA Congress (Govtrack US 2013). Probably the most popular example of wildfire prevention by goats is by Google, in their headquarters of Mountain View campus, in west California; the success of such a low-tech "green mowing" initiative resonates well with the well-publicized global ideal of carbon footprint reduction, underlining that goats are an effective method of nearly carbon-neutral weed control. Since 2009, the presence of 200 goats with their kids and a goat herder, helped by a nice Border collie, delight Google people and public opinion, for goats in many people's eyes are more pleasing to watch than lawn mowers (AFP 2009, Burgess 2009, Kazuki 2009). Goats have also got the green lights from PETA (People for the Ethical Treatment of Animals) which has hired goat to mow its lawn (Kazuki 2009). In Europe, an interesting study case is Matadepera, in the Barcelona Metropolitan Region, where a flock of 200 goats and sheep is being used as a prevention tool by the municipality to control sprouting and to maintain a low fuel load within the coppiced stands (Otero 2010) at a yearly cost of € 20,000.

Use of goats for wildfire prevention

For wildfire prevention purposes goats cannot merely be put out to eat a plant: the proper choice of season of grazing, livestock density, social structure of herd, grazing time per day, type of fencing, size of pens define an appropriate prescribed grazing system, in strict analogy with prescribed burning (Taylor 2006). Prescribed grazing, prescribed herbivory (Pittroff et al. 2006) or targeted grazing can be defined as the application of a specific kind of livestock at a determined season, duration, and intensity to accomplish defined vegetation or landscape goals (Launchbaugh & Walker 2006). Grazing is a complex tool with many plant and animal variables, including: (I) the species of livestock grazed (cattle, sheep, goats, sometimes horses or a combination); (ii) the animals' previous grazing experience (which can affect their preferences for certain plants); (iii) time of year as it relates to plant physiology (animal consumption is directed by the seasonal nutrient content); (iv) animal concentration or stocking density during grazing; (v) grazing duration; (vi) plant secondary compounds; and (vii) animal physiological state (Nader et al. 2007). The use of grazing as a wildfire prevention tool can either be treated as a short-term measure to reduce flammable vegetation (type of plant species and type and amount of biomass to be eliminated: leaves? twigs? stems?) or a long-term measure to change vegetation composition by depleting root carbohydrates in perennials and reducing the soil seed bank for annual plants. The main objectives of wildfire prevention through grazing are to change fire behavior through the modification of the fuel bed, fuel loading, percent cover, and ladder fuels. As an example, Chapman & Reid (2004) report that in a mixed shrubland in Nevada, using a stocking density of 1.1 Animal Unit Month (AUM) per acre for 30 days in May, 73% of the forage was eaten, ground litter was reduced by about 60%, and vegetation height was reduced by approximately 75%. Fire experts estimated this would decrease the rate of spread of a fire by about 75% and reduce the likely height of the flames from 6'-10' (182-305 cm) down to about 2'-3' (61-92 cm). In any case, grazing for wildfire prevention requires skilled herders. Also, the problem of the social stigma attached to goats and goat herders still remains (Green & Newell 1982). Perhaps that stigma comes from the distinctive odor of active breeding male goats (Anonymous 2012).

Goats must be confined in pens of an area of approximately 0.9 hectares which are enclosed by a traditional metal fence, electrified netting or por-wire polywire fence. An electrified fence must be energized by low impedance battery-powered fence energizers, which send a pulse of electricity through the wires, eliminating the possibility of overheating. Solar panels can be used to keep batteries charged. Predators, if any, can be discouraged by electric fencing (Correa 2012). Goats require better fences than sheep or cattle to ensure their containment, namely sheep and goat net wire which has a wider space between the vertical stays. In order to maximize fuel reduction, a high stock density is necessary when a complete elimination of biomass is required (Correa 2012). Existing data indicates there are two ways in which grazing impacts the fuel load; removal of vegetation and hoof incorporation of fine fuels. Tsiouvaras et al. (1989) report that in a California Monterey pine and eucalyptus forest in the fall at a stocking rate of 113 Spanish goats per acre for 3 days, the brush understory was reduced by 46% and 82% at 20 inches and 59 inches in height respectively. Goat grazing not only broke up the sequence of live fuels (horizontally and vertically up to 59 inches), but also reduced the amount of 1-hour dead fuels by 58.3%, although the 100-hour fuels remained constant. The litter depth was also reduced as much as 27.4% (from 2.9 inches before to 2 inches after grazing). Animal trampling which crushed fine fuels and mixed them into the mineral soil thus reduced the chance of ignition. Lindler et al. (1997 in Ingram et al. 2013) reported that goats stocked at 7 per acre for 3 weeks in the summer in a ponderosa pine forest were estimated to remove 15-25% of the vegetation, depending on the plant species present and the length of stay in the pasture. The same authors reported that a stocking rate of 37 goats per hectare in a California pine forest is required to effectively treat understory brush. The high stock density in such a small space creates many trails, which act as minifuel breaks that help break up the continuity of available fuel (Mendenhall 2004, Kirkpatrick et al. 2011, Mancilla-Leytón et al. 2012). Dogs are a main part of the system, even though their barking may not be welcome in some areas such as in the wild land-urban interface. They help to contain livestock and move animals into and out of paddocks and into the trailers for their transport (AFP 2009). Pros and cons: a reduced SWOT We can summarize current knowledge about goats as wildfire prevention tools as reported in Tab. 1 (Pastor et al. 2006, Luginbuhl & Pietrosemoli Castagni 2007, Jáuregui et al. 2009, McGinty et al. 2009, Mancilla-Leytón & Martín Vicente 2012).

Summary and conclusion Prescribed goat grazing has the potential to be an ecologically and economically sustainable management tool for the local reduction of fuel loads, mainly 1h and 10h fine dead fuels and smaller diameter live fuels. These fine dead fuels can greatly impact the rate of spread of a fire and flame height, both of which are responsible for fire propagation (Pastor et al. 2006, Nader et al. 2007, Mancilla-Leytón & Martín Vicente 2012). Far from being a simple technique, prescribed goat grazing is more complex than simply putting a goat out to eat a plant; it requires careful evaluation of the type of animals and planning of timing. The technique also requires further research, since information about grazing for fuel reduction is anecdotal and there is only limited scientific information currently available, mainly for the Mediterranean area (Nader et al. 2007, Kirkpatrick et al. 2011). The economically sustainable use of prescribed herbivory could be used for (Taylor 2006, Diamond et al. 2009, Hudak et al. 2011):

• maintenance grazing of fuel breaks with mixed goat-sheep flocks;

• high impact browsing where prescribed burns are not possible (high-cost service);

• specialized impact browsing in timber plantations (medium/high-cost service);

• follow-up on burned areas (short term).

Goats are the most cost-effective, non-toxic, non-polluting solution available; they are greatly appreciated by the general public and they are an environmentally friendly and effective method of nearly carbon-neutral weed control which deserve further attention and applied research.

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The FarmReal Concept

SECTION 02

The FarmReal Concept

The appearance of unwanted plant species on agricultural properties is a common problem today. The removal of these is usually done using agricultural machines or herbicides, which can raise environmental issues. A more ecologic alternative is the use of cattle to remove this type of plant species. The FarmReal project aims to develop a goat grazing control solution for the removal of invasive plant species and to promote fire prevention. For this purpose, smart collars were developed with sensors and actuators capable of monitoring and controlling the animals' behavior.

The Internet of Things (IoT) has the capability to transform the world we live in; more-efficient industries, connected cars, and smart cities are all components of the IoT equation. However, the application of technology like IoT in agriculture could have the most significant impact.

FarmReal is based on a disruptive community herd concept as a response to curb uncontrolled vegetation growth and ensure the recovery of soil fertility.

In addition to assuming an essential role in the prevention of forest fires, this platform allows users to be "virtual shepherds" of real goats. Users can follow the day-to-day life of the adopted goats, monitoring their behavior and socialization through updated photos and videos, their GPS location, as well as the area and amount of vegetation deforested by the herd.

In addition to helping shepherds identify issues in real time, smart FarmReal collars aggregate all of the information they gather, storing it in a user-friendly database. This comprehensive set of information gives shepherds a powerful tool to help make long-term herd management decision. Data can be accessed about individual animals or the herd as a whole. Graphs and reports chart movement patterns, grazing routes, activity, distance traveled and time spent resting. Maps show routes traveled by animals during a given time period.

Planned actions

SECTION 03

Planned actions

Ref No.	Title of actions planned or taken	Brief summary of action	Expected (or actual) output & results	How local stakeholders were involved in planning & implementing the action	State-of-play of implementation
1	Development of proof-of-concept – goat collar	In this task we aim to start the design of the MVP regarding the technical features to collect important information how to use goat herds grazing along the hillsides, eating unwanted grasses and weeds for fire-prevention	• Technical requirements • Important features to measure: goat physical activity, goat walking distance, goat eating patterns	Local community members were involved by providing valuable information regarding goat routine information, important considerations to take into account when developing the goat collar (weight, dimensions, autonomy)	Action is completed, 3 interview events with local stakeholders were held
2	Set-up platform 1.0	Development of the online platform to collect data for goat activity and eating pattern (amount & area)	• Initial version of the platform (website) with the aim to collect initial data for validate technological concept	Local stakeholders were involved by validate features to include, providing feedback and testing	Action is completed – final testing
3	Development of Shepherd App 1.0	Development of the app designed for shepherd to	• Technical requirements • User-friendly layout • Launch the	Local shepherds were involved to provide valuable	Action is on-going, final adjustments are required

Ref No.	Title of actions planned or taken	Brief summary of action	Expected (or actual) output & results	How local stakeholders were involved in planning & implementing the action	State-of-play of implementation
		collect multimedia information to be integrated in the platform website	version 1.0	insights regarding app UI/UX and usability as end-users (e.g: main menu interaction)	(e.g.: implement app to also work offline due to signal restrictions in the area)
4	Usability-testing of the Shepherd App and Platform (website)	Usability testing will be all about getting a small group of external people to interact with the website (general public) /app (other shepherd) and observing their behaviour and reactions to it	• Validate the prototype reliability • Identify issues with complex flows • Complement and illuminate other data points • Catch minor errors	Action with 30+ community members – general public and shepherds (but not currently involved in the FarmReal project)	Action is almost finished; however, we are continuing looking for feedback and collecting data
5	Release Platform and Shepherd App 2.0	Implement the feedback from the previous task into the platform and website	• Release of version 2.0 – Platform (website) and App providing a better user experience	Local community validated final requirements before the implementation of the version 2.0 and will test when it will be release	Action is completed, specialist support was needed from website and app developer
6	Technology Impact Assessment	Validate technical and environmental assumptions: Goat herds to	• Validate Farmreal as a tool for enhance controlled	Shepherds were involved to guarantee the running of the pilots –	Action is on-going; specialist support will be needed to

Ref No.	Title of actions planned or taken	Brief summary of action	Expected (or actual) output & results	How local stakeholders were involved in planning & implementing the action	State-of-play of implementation
		reduce and prevent wildfire provides another cost-effective option to the current most used fire-fighting solutions such as pesticides and mechanical equipment	grazing as a cost-effective option for fire prevention • Social Impact Assessment • Validate value proposition (euro spent per m^2 of deforested area) • Measure and monitor results and to anticipate accordingly.	establishing a grid for targeted vegetation removal, keeping the goats in the area where we could be measuring the deforest area, tracking and validating goat eating patterns. Local stakeholders were involved to provide information about costs regarding goat herd maintenance and costs identification regarding mechanical equipment approach, among others.	collect and analyse the information for technology impact analysis

Validating FarmReal

SECTION 04

The FarmReal Solution

The identification and validation of the actual unmet needs aligned with the Ferraria São João challenges enabled the co-design of the corresponding specific key areas/functionalities of a user centric and integrated solution for smart farming and fire prevention.

The requirements documented here represent the defining features of the new FarmReal platform which, individually and in total, represent significant innovation beyond the state of the art in the management of goat grazing.

These new requirements were co-designed with Ferraria de São João during 2021 and 2022.

Req. ID	Function text	Requirement text
FR01	Device design	All physical devices/hardware need to be weatherproof/protected to work (and be safe i.e. battery not overheating/risk of exploding etc.) in reasonable harsh conditions. This includes cold/heat/rain/wind resistance as well as visibility for screens (different light conditions/rain) etc.
FR02	Device design	All physical devices/hardware need to be easily detachable for cleaning.
FR03	Battery	The smart Collars need to be powered by batteries with long life before the need to be recharged. Some kind of easy indication/feedback that each specific tool is on or off is needed as well as well as simple charging options without need to dismantle things.
FR04	Data-flow	The interaction with the tools, the feedback loop and the information representation need to happen in real time or near real time.
FR05	Deployment	All devices need to be easy to carry, transport and deploy.
FR06	Easy to operate	All devices need to be easy to operate both hardware wise and software wise.

FR07	Data Transmission	All wireless data transfer needs to be working in different "connection conditions"; "Connection lost" indication is needed.
FR08	System Reliance	Tools should be able to self-diagnose in order to check that all functionalities are working well before acting.
FR09	Data Storage	All data collected and transmitted by components/systems must be stored and be available for post processing i.e. in a database that is easy to extract information from.
FR10	Gateway	The gateway must be capable of receiving signals from the device for a 2km radius, minimum.
FR11	Error	The device must receive coordinates with an error of no more than 20m.
FR12	Power and connectivity	The Smart Collar will determine wireless protocols based on power and connectivity.
FR13	Coordination	Coordinate location signals will be received every 15 seconds during active time. Coordinate signals consumes a significant amount of power, reducing the duty cycle will reduce power consumption.

Engineering Standards Specification

Safety

Standard	Use
Pet Friendly	In no way harmful to any animal
User Friendly	Cannot shock or harm the user

Communication

Standard	Use
RS232	GPS module interfacing
GNSS	Satellite signal communication
LoRaWAN	Data transfer from device to gateway
WIFI	Device tracking, short range

Data Format

Standard	Use
NMEA	Standardized GPS data format
LoRa	Standard LoRa
802.11	Standard WIFI

Design Methods

Standard	Use
LTspice	Circuit design
Teseo-Suite	GPS module configuration
Flutter	Smartphone application design
Atom-Pymakr	Programming Pycom
Eagle CAD	Schematic layout
Android Studio	Integrated development environment

Programming Languages

Standard	Use
C	NMEA data translation
MicroPython	Pycom programming
Dart	Flutter programming for application

Connector Standards

Standard	Use
RS232	GPS module to microcontroller interfacing
MicroUSB	Recharging of device

Accepted Technical Design

Level 1 Hardware Design

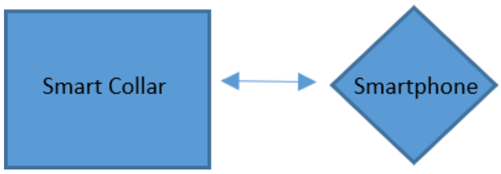


Figure 5: Level 1 hardware diagram depicting general data flow between the Smart Collar andthe user's smartphone.

FR Smart Collar module

Module	Smart Collar
Inputs	User preferences, wireless communication data.
Outputs	Coordinates data.
Functionality	To operate as a wireless tracking system, using multiplewireless communication abilities. The Smart Collar will be programmable via a smartphone application.

FR smartphone module

Module	Smartphone
Inputs	User preferences, Smart Collar data (location, batterylife, current settings).

Outputs	User preferences and settings.
Functionality	To operate as the control module for the collar, whilebeing able to view the location of said tracker via an application.

Level 2 Hardware Design

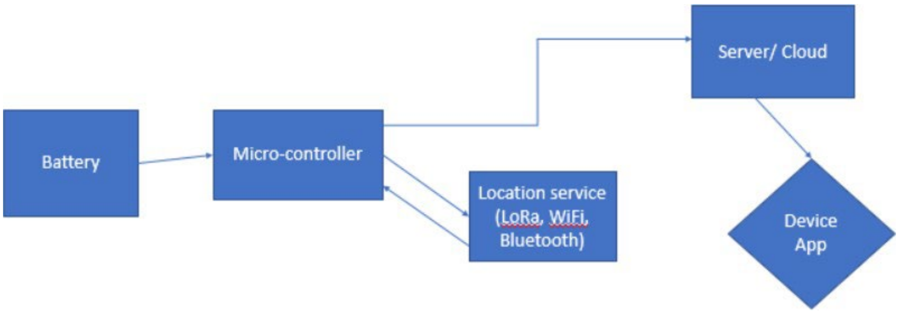


Figure 6: Level 2 hardware diagram depicting a more in-depth data flow between components.

FR battery

Module	Battery
Inputs	Power from an average household wall outlet (120V,60Hz, 15A).
Outputs	Power to the microcontroller.
Functionality	To generate power for the entire device.

FR Microcontroller

Module	Microcontroller
Inputs	Location coordinates, user preferences, battery power.
Outputs	Requesting coordinates, data transfer.

Functionality	Computer of the device, processing data and commanding functionality from the other modules of the device.

FR server

Module	Server/Cloud
Inputs	Data transmitted from the gateway and data transmittedthrough the smartphone via the application.
Outputs	Data transmitted from the gateway and data transmittedthrough the smartphone via the application.
Functionality	To communicate between the user via the application andthe device via the gateway.

FR Smartphone application

Module	Smartphone Application
Inputs	User inputs
Outputs	Data controlling preferences on the Smart Collar as wellas a digital map to track device
Functionality	To control the device settings and used as a real-timedigital map to track and locate the device.

Level 3 Hardware Design

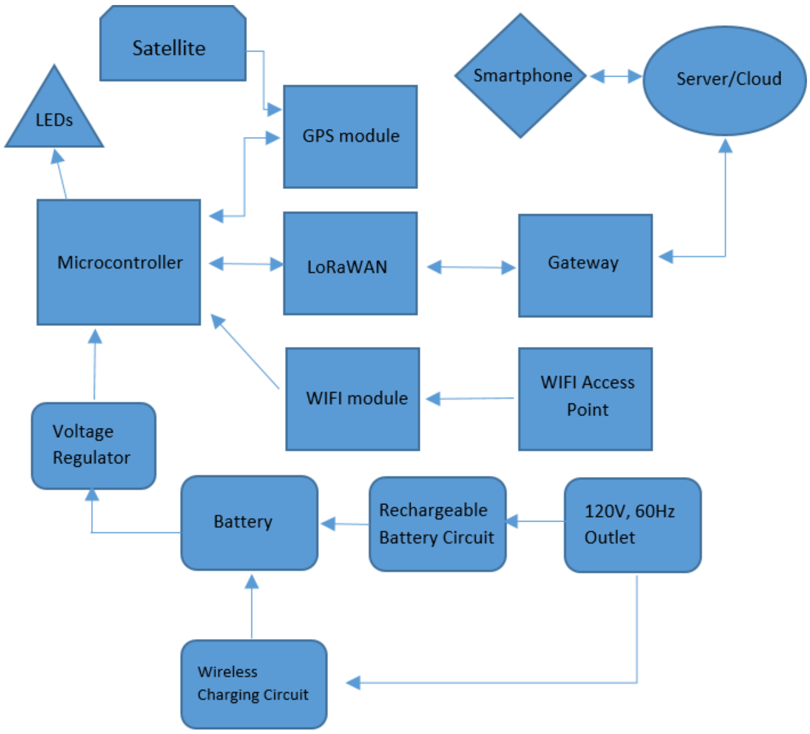


Figure 7: Level 3 hardware diagram depicting more detailed function between the components.

FR Lithium-Ion battery

Module	Lithium-Ion battery
Inputs	Power from the rechargeable circuit: -5V -1.2A
Outputs	Power: -3.7V -200mA max -1 A/hr capacity
Functionality	To generate power for the entire device with the capability of being recharged to negate the need forbattery replacement.

FR Gateway

Module	Gateway
Inputs	Data transmitted through the LoRaWAN module anddata transmitted through the server.
Outputs	Data transmitted through the LoRaWAN module anddata transmitted through the server.
Functionality	To communicate between the server and the LoRaWANmodule while boosting the transmit distance to a minimum of 2km.

FR GPS module

Module	GPS Module
Inputs	Global coordinates received by satellite (GNSS)3.3V
Outputs	National Electronics Marine Association (NMEA) data
Functionality	Receive and send data from satellite to microcontroller

FR LoRaWAN

Module	LoRaWAN

Inputs	Data regarding location of tracker, current battery status,and WIFI signal visibility.
Outputs	All data being sent to the LoRaWAN module will betransmitted through the module to the gateway.
Functionality	To control the data transmission from the microcontrollerto the gateway.

FR microcontroller

Module	Microcontroller
Inputs	Translated GPS coordinates, Downlink from LoRaWAN, WIFI signal/s, Input voltage
Outputs	Requesting GPS coordinates, transferring data throughLoRaWAN
Functionality	Computer of the device, processing data and commanding functionality from the other modules of thedevice.

FR recharge circuit

Module	Rechargeable Battery Circuit

Inputs	120V, 60Hz, 15A (1.8kW) from a normal wall outlet
Outputs	Power (1.2A, 5V, 6W)
Functionality	To convert and control the input power from the walloutlet into power recharging the battery in the device.

FR satellite

Module	Satellite
Inputs	N/A
Outputs	Global positioning coordinates.
Functionality	To acquire location of GPS module and transmit data tosaid module.

FR server

Module	Server/Cloud

Inputs	Data transmitted from the gateway and data transmittedthrough the smartphone via the application.
Outputs	Data transmitted from the gateway and data transmittedthrough the smartphone via the application.
Functionality	To communicate between the user via the application andthe device via the gateway.

FR smartphone application

Module	Smartphone Application
Inputs	User inputs
Outputs	Data controlling preferences on the Smart Collar as wellas a digital map to track device
Functionality	To control the device settings and used as a real-timedigital map to track and locate the device.

FR voltage regulator

Module	Voltage Regulator

Inputs	Battery Voltage (3.7V)
Outputs	3.3V
Functionality	To raise and lower voltage levels accordingly for safe and proper operation by the microcontroller and device

FR WIFI module

Module	WIFI Module
Inputs	WIFI signals generated by the WIFI access point.
Outputs	All visible WIFI beacon frames.
Functionality	To receive WIFI signals to be used to check if device iswithin parameters.

Technical validation of developed prototypes

The validation of the developed prototypes has been carried out by a pilot at Ferraria de São João, which is still ongoing. However, for demonstrative purposes, we present the pilot that took place in the period between January 14 and May 2, 2022, with the participation of five animals.

For the validation tests during the pilot, the following equipment was used:

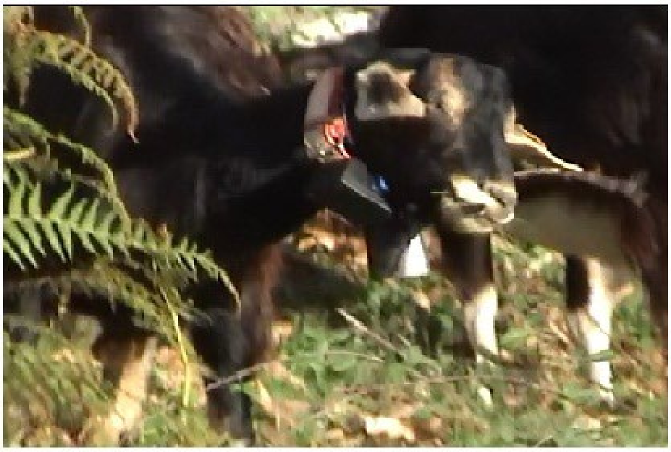
- 1 Laptop computer;

- 1 *Smartphone* with Android operating system;
- 1 Video aggregation, processing and sending module (consisting of a processing unit, a router and a 3.5G modem);
- 2 outdoor Wi-Fi video cameras;
- 5 Smart Collars;
- 1 Web server.

For the implementation of the pilot, three *standard collars were installed* on three animals and a super collar on the fourth animal. The two video cameras were installed in the immediate vicinity of the animals' grazing site and the aggregation, processing and video sending module was also installed in an indoor environment close to the cameras.

During the pilot, the animals were monitored daily through the developed collars and video cameras. These transmit the videos, through the Wi-Fi *router*, to the aggregation module, which in turn processes and temporarily stores them until they are sent to the Web server, via 3.5G modem, every hour during the day. In turn, the *standard collars* acquire information regarding the distance traveled, agitation and distance from the other animals. In addition to the parameters mentioned above, the super-collars have the ability to acquire the GPS location and aggregate the data from the remaining nodes, forming a WSN. Every two hours, the super-collar sends the collected information to the web server, via GPRS. On the web server, the information is validated, processed and stored in the database for later presentation on the web platform. In addition to the images collected by the permanently installed cameras, the application for Android devices was also tested, which allows taking photos and recording videos, in addition to allowing the management and sending of this content to the Web server.

Taking into account the presented scenario, the tests were carried out, which we will systematize below for the various modules.

web server

The Web Server consists of four modules, namely, a database, a video processing module, a *back office* and a Web platform. The database allows you to store all the information regarding the animals and their collars, as well as the users of the Web platform.

back office

In the *backoffice,* all information (videos, photographs, animal data, farms, among others) to be shown to system users on the web platform is managed and processed.

Authentication test

Description	Description: Check the functioning of the *backoffice* . Input : • Access the system *backoffice* .

	• Enter valid *login* and *password* to access the system.
Results	Criteria: The *backoffice* home screen is displayed . Result: Behavior as expected.

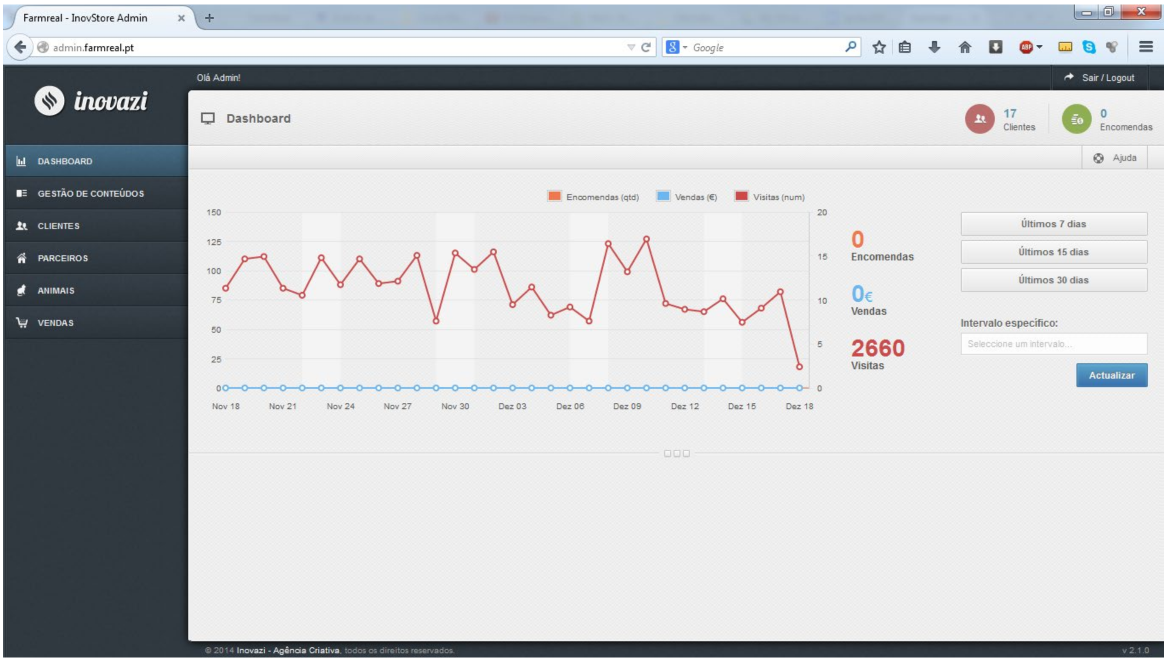


Figure 1– *Backoffice dashboard* with platform statistics.

Test the content tab

Description	Description: Check the functioning of the *backoffice* . Input : • User authenticated in the *backoffice* . • “Content Management” option. • Edit the contents of the “Project” tab. • Form submission.
Results	Criteria : *Front-end* reflects content editing. Result: Behavior as expected.

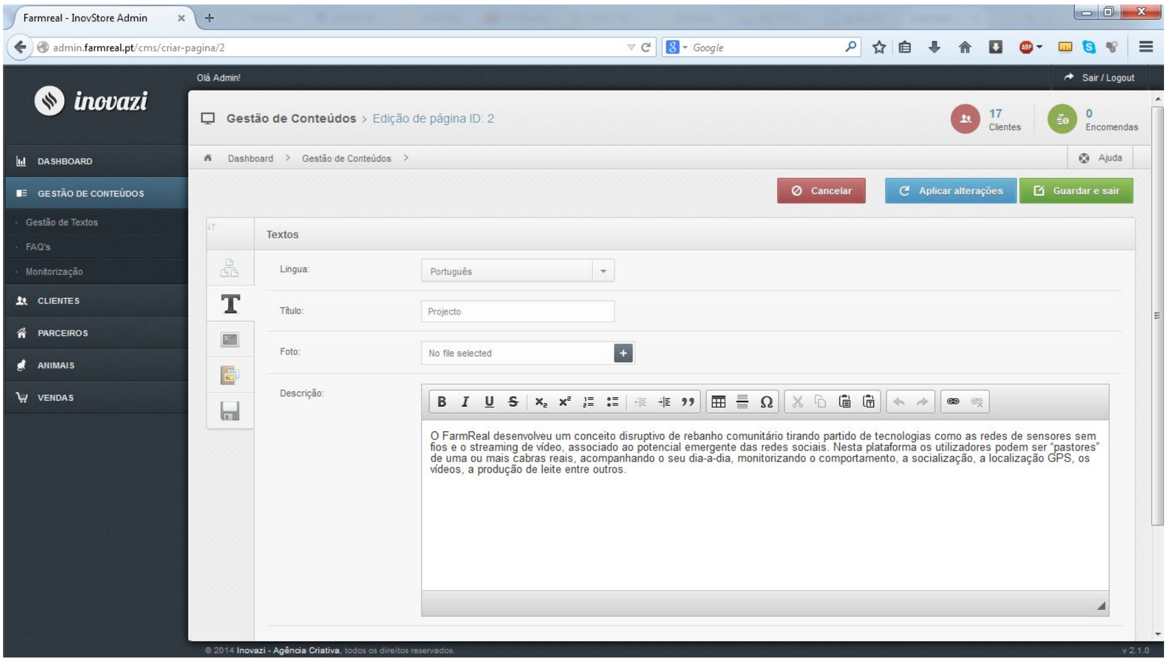


Figure 2– Content management separator *dashboard* .

Test the Customer Management tab

Description	Description: Check the functioning of the *backoffice* . Input : • User authenticated in the *backoffice* . • "Customer Management" option. • Filling in customer data. • Form submission.
Results	Criteria: Client authenticates to the *frontend* . Result : Behavior as expected.

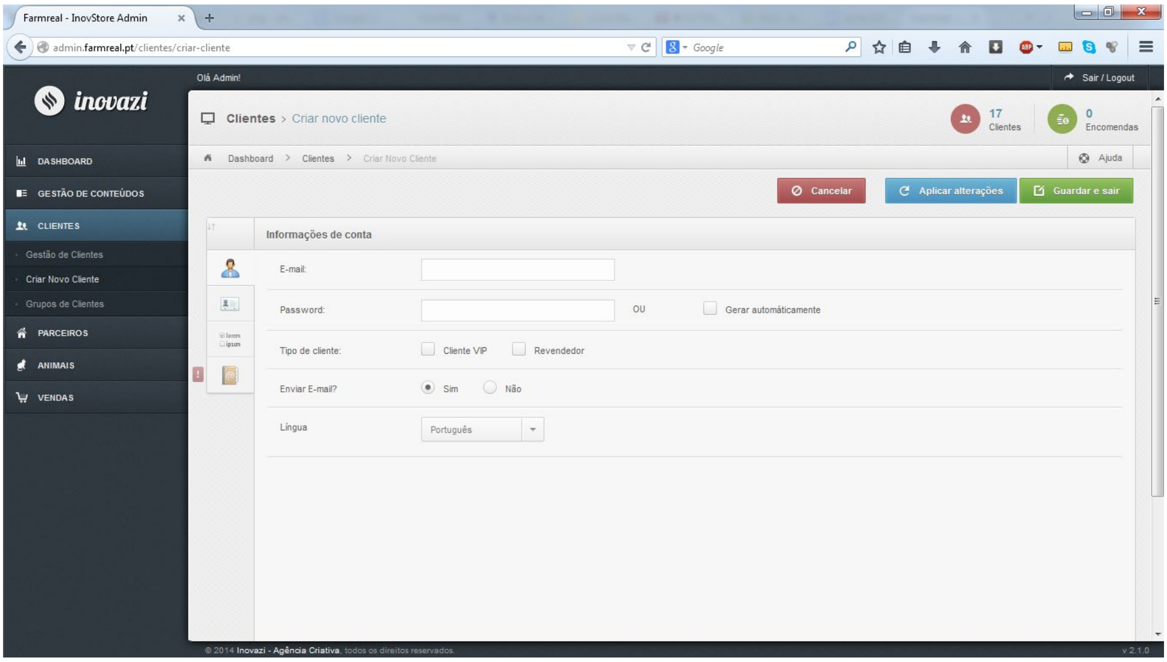


Figure 3– Customer management separator *dashboard* .

Test the Activity Management tab

Description	Description : Check the functioning of the *backoffice* . Input : • User authenticated in the *backoffice* . • “Activity Management” option in the “Partners” tab. • ”Create New Activity”. • Form submission.
Results	Criteria : *Front-end* reflects the insertion of a new activity in the “Schedule of Activities” tab. Result : Behavior as expected.

Test the Herd Management tab

Description	Description: Check the functioning of the *backoffice* . Input : • User authenticated in the *backoffice* . • Option to add a new herd "Penela". • Filling out the form. • Form submission.
Results	Criteria: *Front-end* reflects the insertion of a new herd. Result: Behavior as expected.

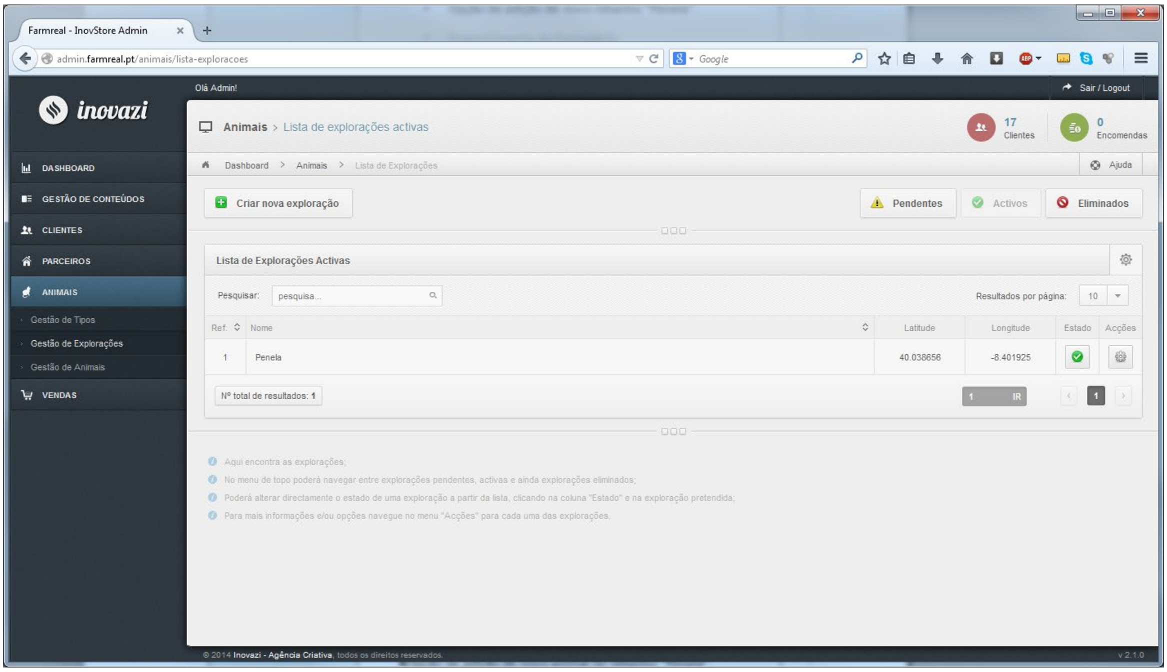


Figure 4– Exploitation management separator *dashboard* .

Test the animal management tab

Description	Description: Verification of the functioning of the *backoffice* . Input :

	•User authenticated in the *backoffice* . •Option to add a new animal to the “Penela” herd. •Filling out the form. •Form submission.
Results	Criteria: When selecting the “Penela” herd, the new animal to be adopted appears. Result: Behavior as expected.

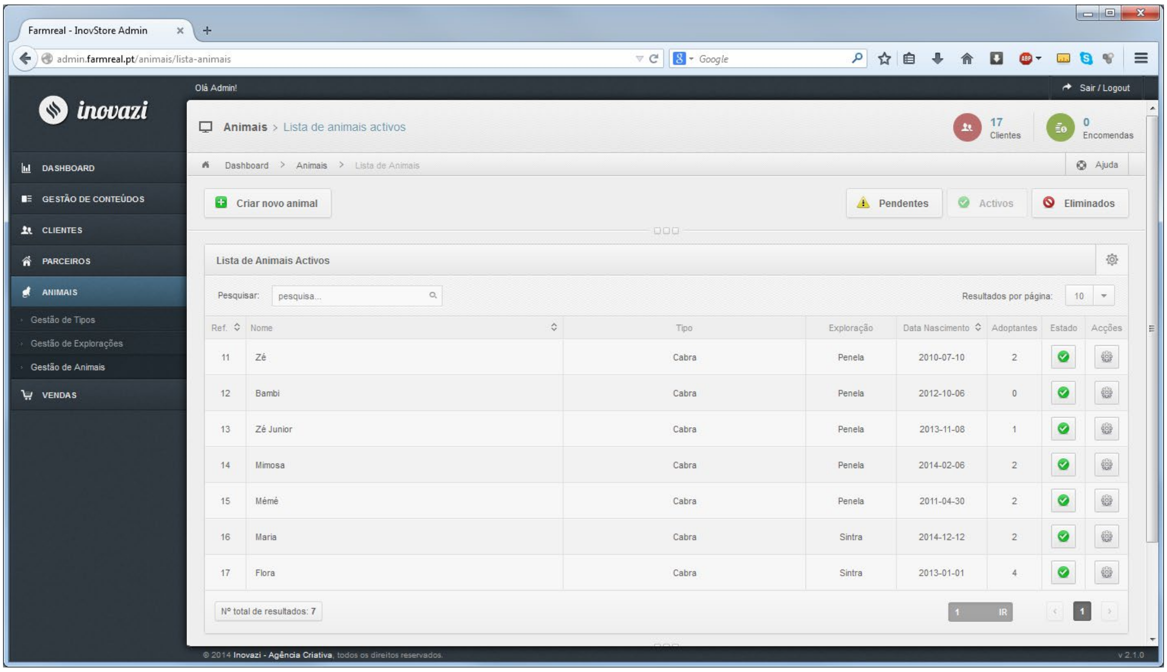


Figure 5– Animal management separator *dashboard* .

Test the animal photo management tab

Description	Description: *Backoffice* validation . Input : •*Backoffice* authentication . •Access the Photo Menu. •Edit photo information.

	•Form submission.
Results	Criteria: Edited photographs appear with details entered. Result : Behavior as expected.

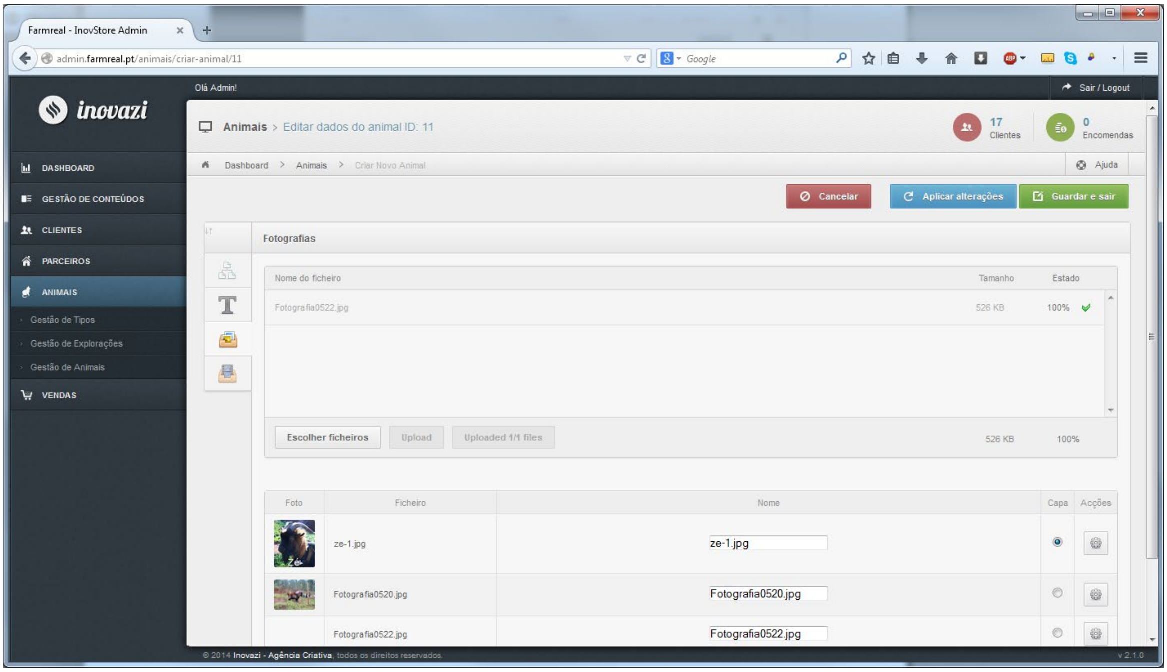


Figure 6– *Dashboard* separator for adding photos to animals.

Test the animal photo management tab

Description	Description: *Backoffice* validation . Input : •User authenticated in the *backoffice* . •Form for editing the details of the videos. •Form submission.
Results	Criteria : When accessing the *front-end* , videos tab, we check the video details. Result: Behavior as expected.

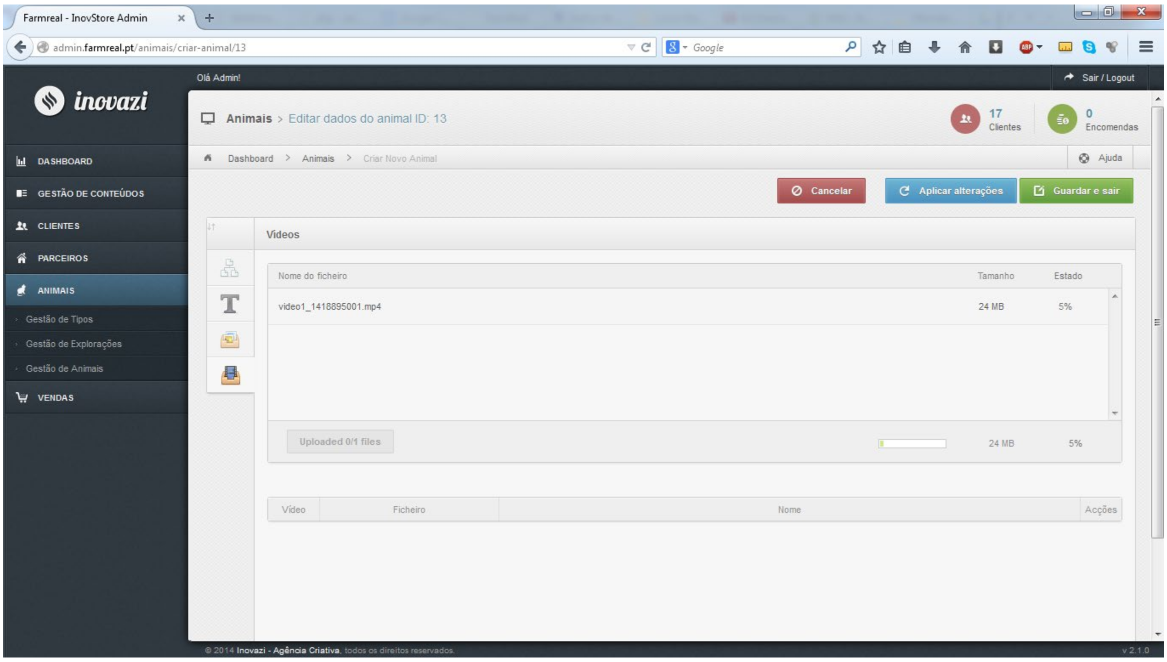


Figure 7– *Dashboard* in the adding videos tab.

Web Platform (frontend)

The web platform provides users with information about the animals, their daily lives, videos and photographs captured on site. It is also possible to consult the rankings of the animals, related to Physical Activity, Happiness and Milk collected from the goats.

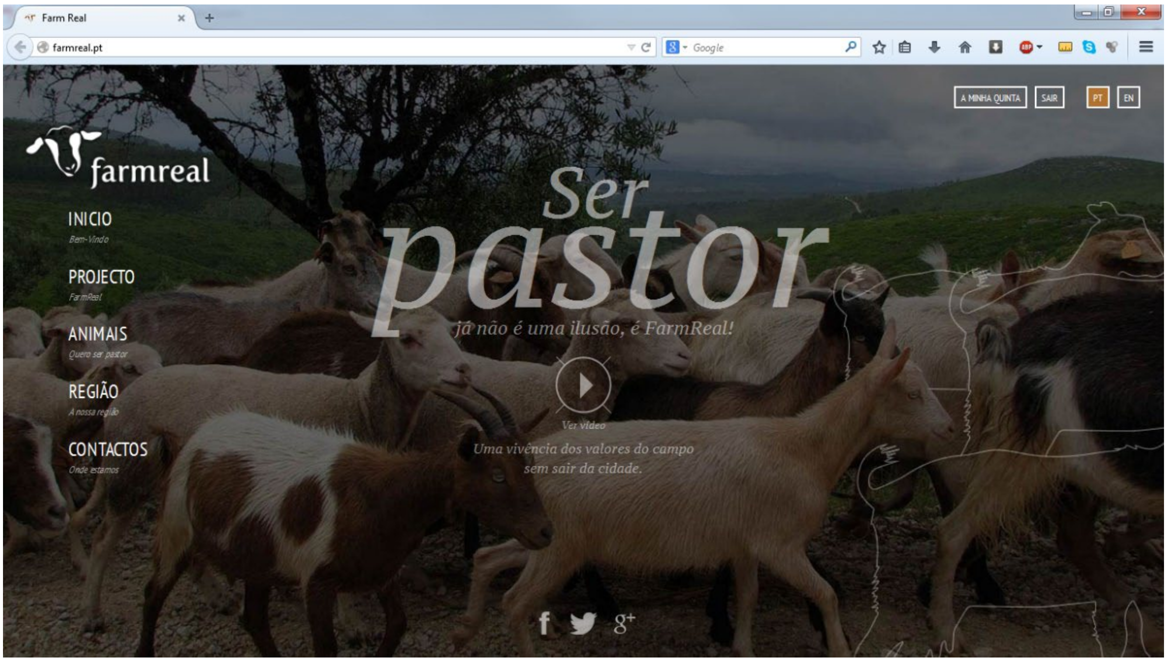


Figure 8– Platform home screen.

Authentication Test 1

Description	Description: Evaluate authentication on the platform. Input : • Access the platform at www.farmreal.pt. • Hit the *login button* . • Put a valid user. • Enter a valid *password* . • Press the *submit button* . • User has not adopted animals yet.
Results	Criteria : The user is redirected to the adoption area. Result: Behavior as expected.

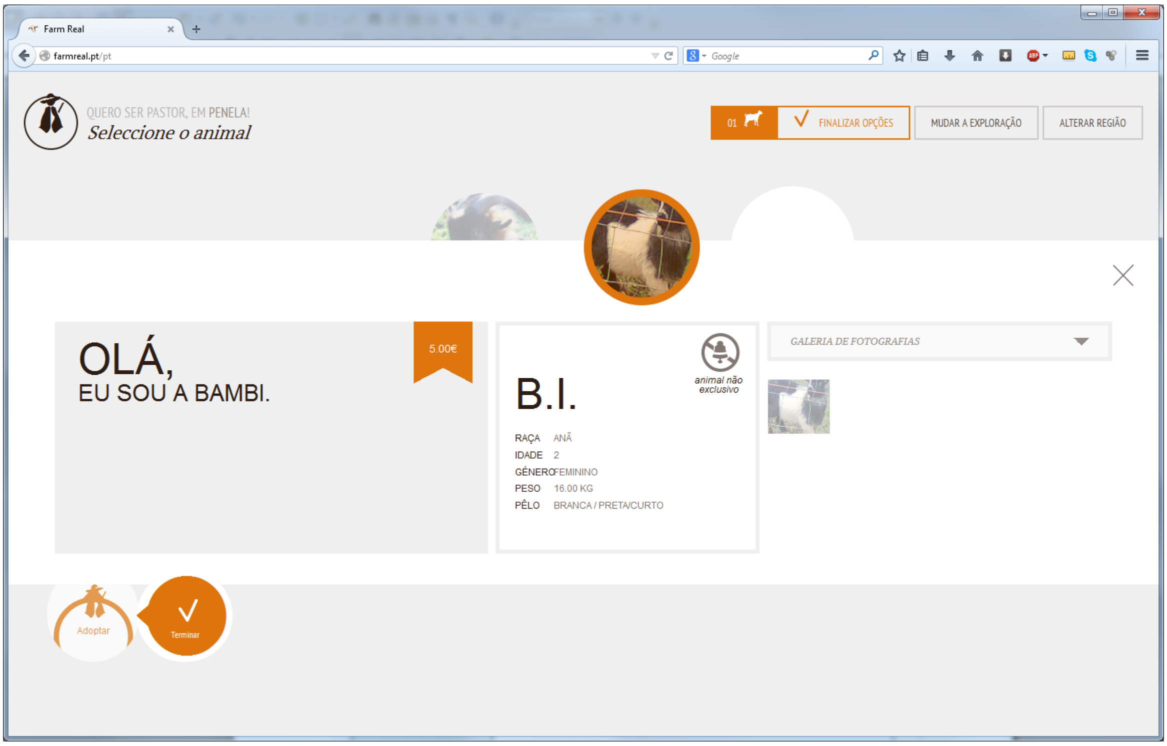


Figure 9– Animal adoption tab.

Authentication Test 2

Description	Description: Evaluate authentication on the platform. Input : • Access the platform at www.farmreal.pt. • Hit the *login button* . • Put a valid user. • Enter a valid *password* . • Press the *submit button* . • User has already adopted animals.
Results	Criteria *:* The user is redirected to the *dashboard* . Result: Behavior as expected.

Test the socialization separator dashboard

Description	Description *:* Verification of the socialization of animals over time. *Input :* •Authenticated user. •*Dashboard* tab . •Expand relationships. •Select the goat “Mémé”.
Results	Criteria: Verify that the best friends are consistent with what is observed on the spot. Result: Behavior as expected.

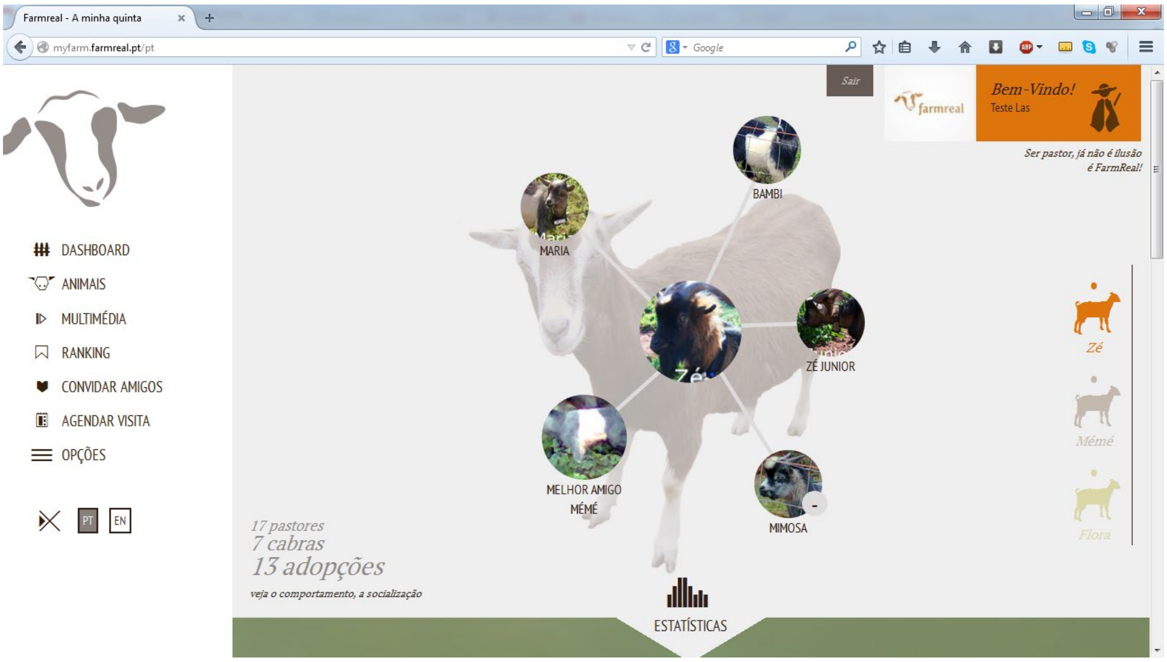


Figure 10– Animal socialization tab on the web platform *dashboard* .

Test the statistics separator dashboard

Description	Description : Verification of animal statistical data. *Input :* •Authenticated user. •*Dashboard* tab . •“Statistics” area. •Select “Zé”.
Results	Criteria: Data are consistent with observed on site. Result: Behavior as expected.

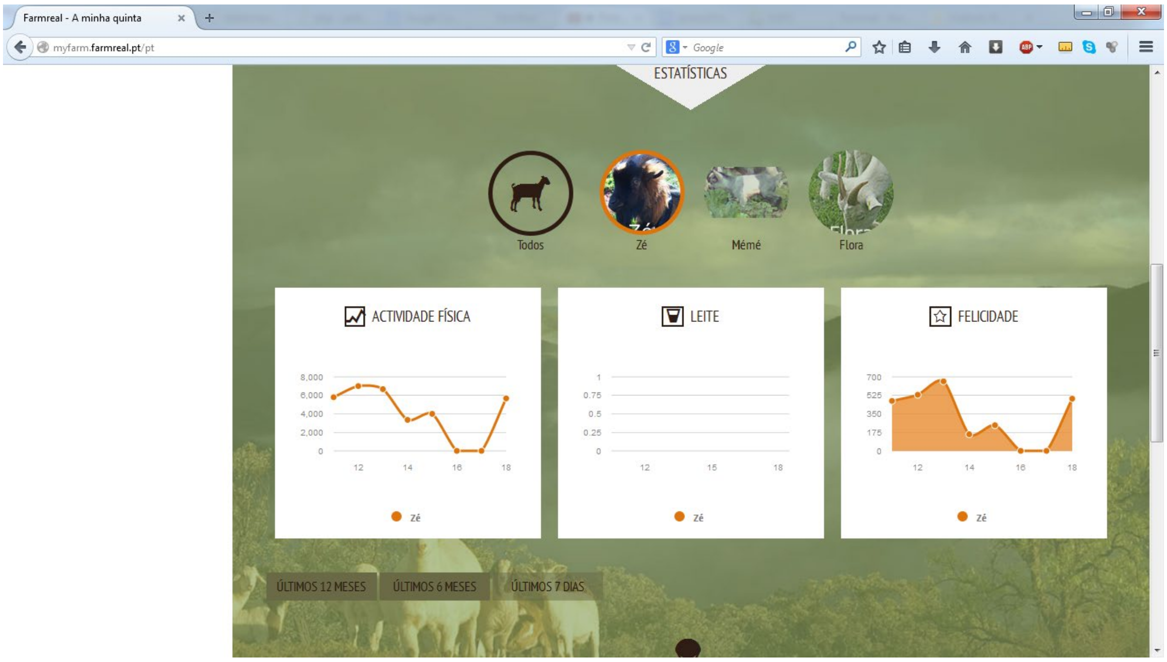


Figure 11– Animal statistics tab on the web platform *dashboard* .

Test the location separator dashboard

Description	Description *:* Checking the location of animals on the map. Input : •Authenticated user. •*Dashboard* tab . •At the bottom of the page appears the map. •Select the goat “Mémé”
Results	Criteria: The animal's path appears on the map. Result: Behavior as expected.

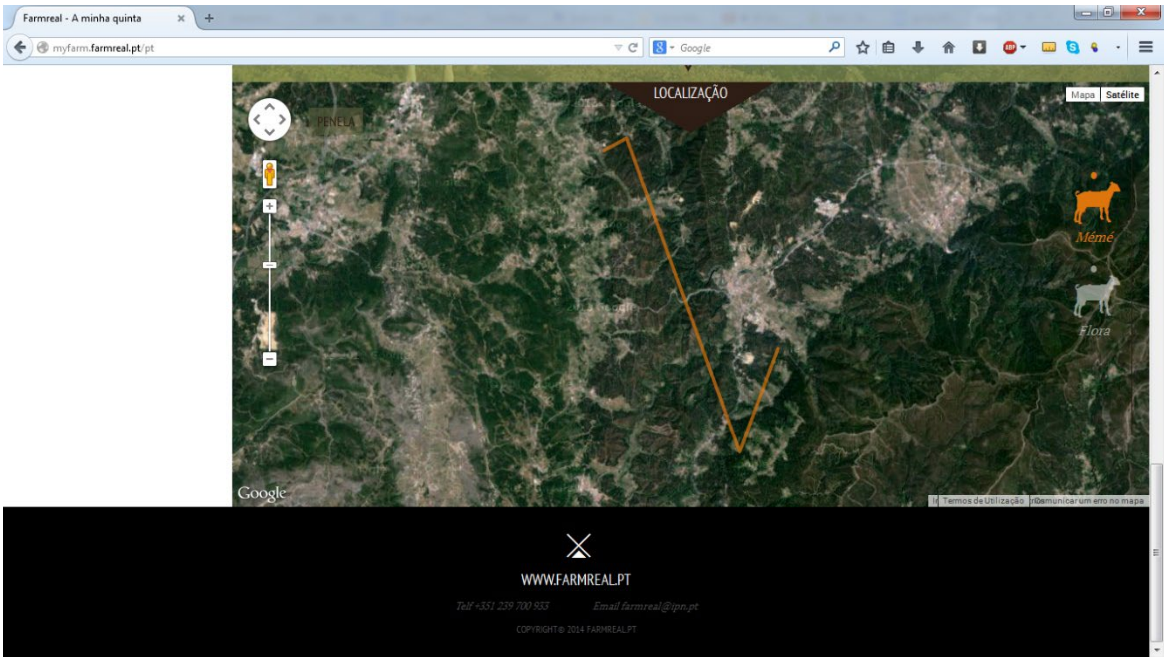


Figure 12Web platform *dashboard* location statistics tab .

Overall ranking test

Description	Description : Checking the rankings. Input : • Select the “ranking” tab. • Select “All”.
Results	Criteria: Check if the animal with the highest score in the *dashboard statistics* is at the top of the ranking. Result: Behavior as expected.

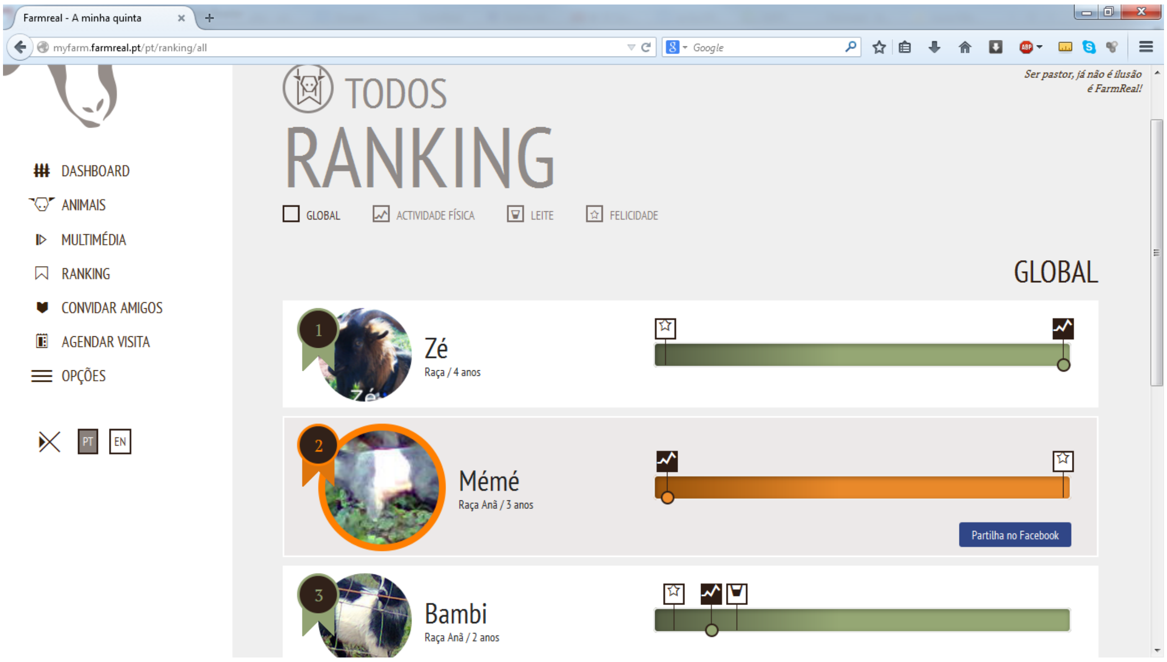


Figure 13– Global ranking of animals.

Test the Visit Scheduling tab

Description	Description: Checking the visit schedule Input : • Select the "Schedule Visit" tab. • Select accommodation. • Select activities. • Set visit dates. • Submit the form.
Results	Criteria: If the dates are later than the current one, the form is submitted and the request is entered into the system. Result: Behavior as expected.

Figure 14– Separator for scheduling visits to the herd.

Application for Android mobile devices

The application for *smartphones* and *tablets* with Android operating system, allows the handler and the visitors of the flock, to publish directly on the platform the photos and videos collected on site.

Test capturing and *uploading* photographs

Description	Description: Checking the functioning of the Android application. Input : • *Smartphone* or *tablet* with Android 4.0.3 operating system (API level 15). • FarmReal application installed on *smartphone/tablet* . • A photograph is captured. • *upload* option is selected . • The photo is sent to the server.
Results	Criteria: The captured photo is sent to the server.

	Result: Behavior as expected.

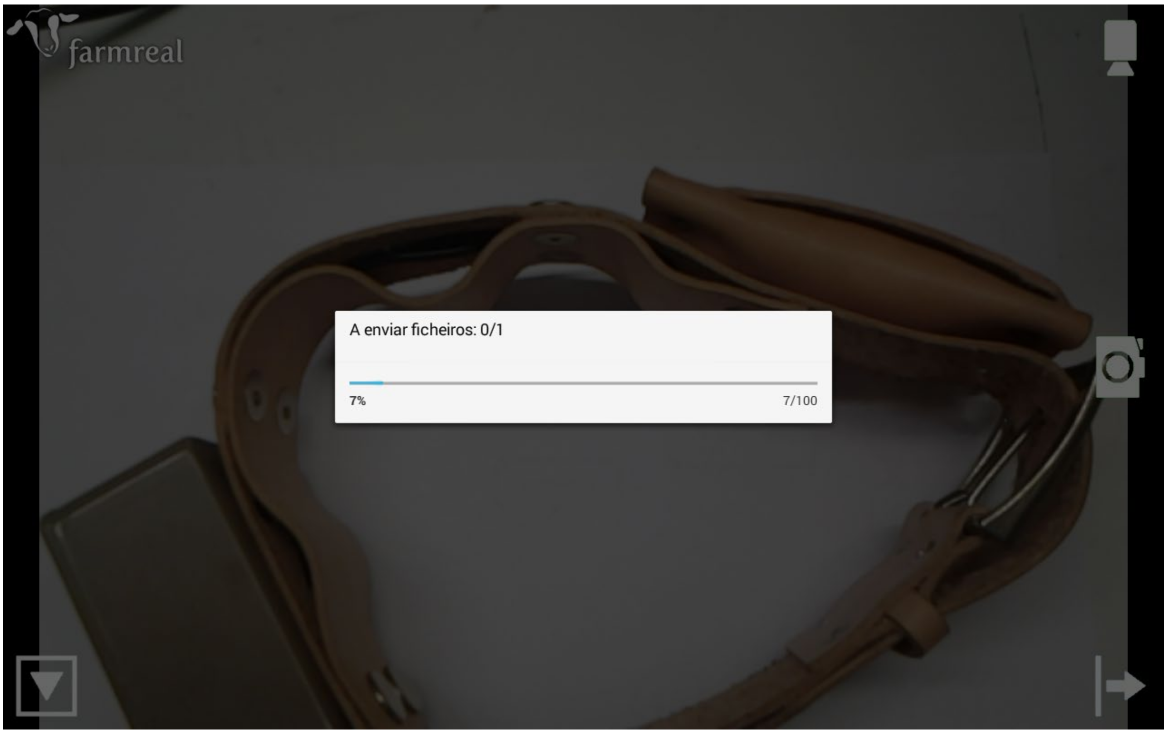


Figure 15– Mobile application *uploading* images.

Test capturing and *uploading* videos

Description	Description: Checking the functioning of the Android application. Input : • *Smartphone* with Android operating system. • FarmReal application installed on *smartphone* . • Capturing a video via *smartphone* . • *upload* option is selected . • The video is uploaded to the server.
Results	Criteria: The captured video is placed on the server.

	Result: Behavior as expected.

Figure 16– Mobile application for collecting and *uploading* videos and photographs.

Testing the availability of photographs on the platform

Description	Description: Verification of the appearance of images submitted on the platform. Input : •*online* platform . •Go to the Multimedia menu. •Consult the photographs and check if the collected images are in the gallery.
Results	Criteria: The captured images appear in the photo gallery. Result: Behavior as expected.

Test the availability of videos on the platform

Description	Description: Verification of the functioning of *uploading* videos on the web platform. Input : • *online* platform . • Go to the Multimedia menu. • Consult the photos and verify that they are in the photo gallery.
Results	Criteria: Videos are available in the video gallery. Result: Behavior as expected.

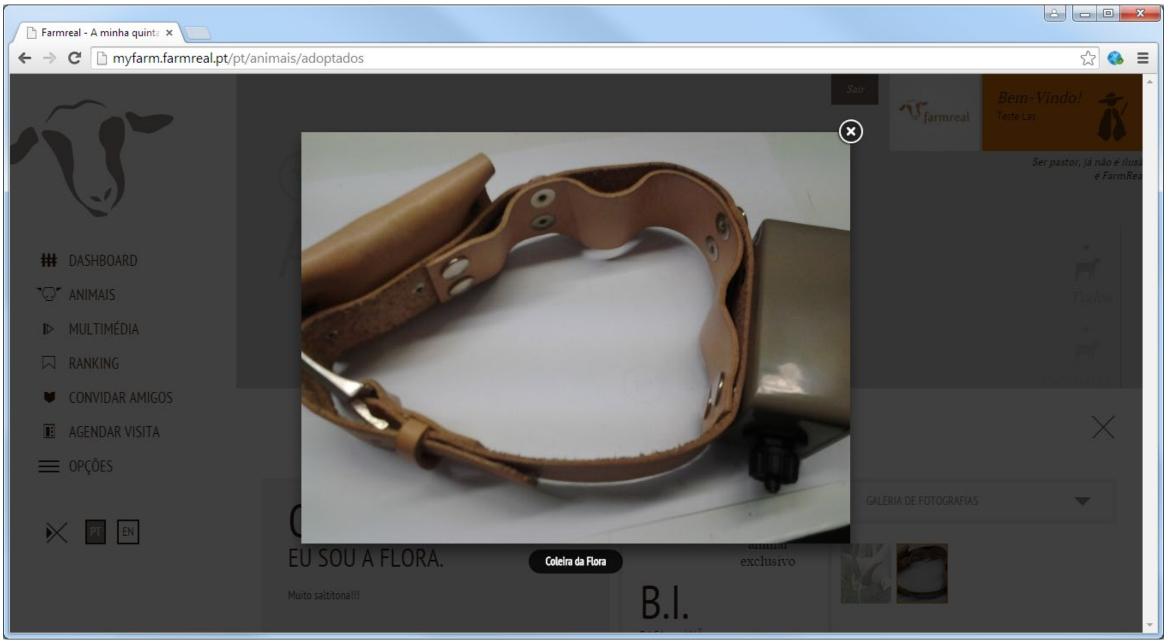


Figure 17– Photographs of the Mobile Application on the platform.

Smart Collars

The collars developed have reduced size and weight, so that they are as natural as possible for the animals. From the observation carried out, it was concluded that even the smaller animals adapted easily, in exactly the same way as a traditional collar.

Sensor calibration test

Description	Description: Check sensor calibration. Prohibited: • Put the collars on the 5 animals. • Distribute the remaining necklaces around the perimeter of the fence. • Visually identify collars. • Record the installation time. • Analyze the data received on the server in the following 2 communications.
Results	Criteria: After installation, the collars that are static send data of distance traveled and agitation equal to 0 and the others send values greater than 0. Result: Behavior as expected.

Calibration test of accelerometer and distance traveled sensors

Description	Description: Check sensor calibration. Input : • Put the collars on the 5 animals. • In the interval between communications, observe the movement of the animals and estimate the distance covered by them. • Check the type of movements performed that will impact the accelerometer. • Record the proximities between the animals.
Results	Criteria: The data received at the server translates the observed behaviors.

	Result: Behavior as expected.

Testing the GPS sensor calibration

Description	Description: Verification of sensor calibration. Input : • Place the collar with ID 1 on one of the animals. • Collect the GPS coordinates of the perimeter with an auxiliary device.
Results	Criteria: The data received through the collar with ID 1 on the server conforms to the GPS coordinates of the exploration area. Result: Behavior as expected.

Test the impact of data on the platform

Description	Description: Check sensor calibration. Input : • Observe the animal with collar 1 during the interval between communications. • Analyze the data received on the server in the next communication. • Analyze the animal's location map in the " *dashboard* " tab.
Results	Criteria: GPS data is translated by distance traveled in the range. Result: Behavior as expected.

Videos

The video acquisition system works during the day in the immediate area of the stable, these are activated by the detection of movement by the animals. These captures are stored in the SBC which sends them to the web server every hour. On the web server the videos are aggregated and converted to *mp4* so that they can be played on the web.

Test to update videos on the platform

Description	Description: Verification of the platform update by the remote system. Input : • Authenticate on the platform. • Access the "Videos" tab and view the latest video. • Return to platform after 1 hour. • The gallery has new videos.
Results	Criteria: The video gallery is updated throughout the day. Result: Behavior as expected.

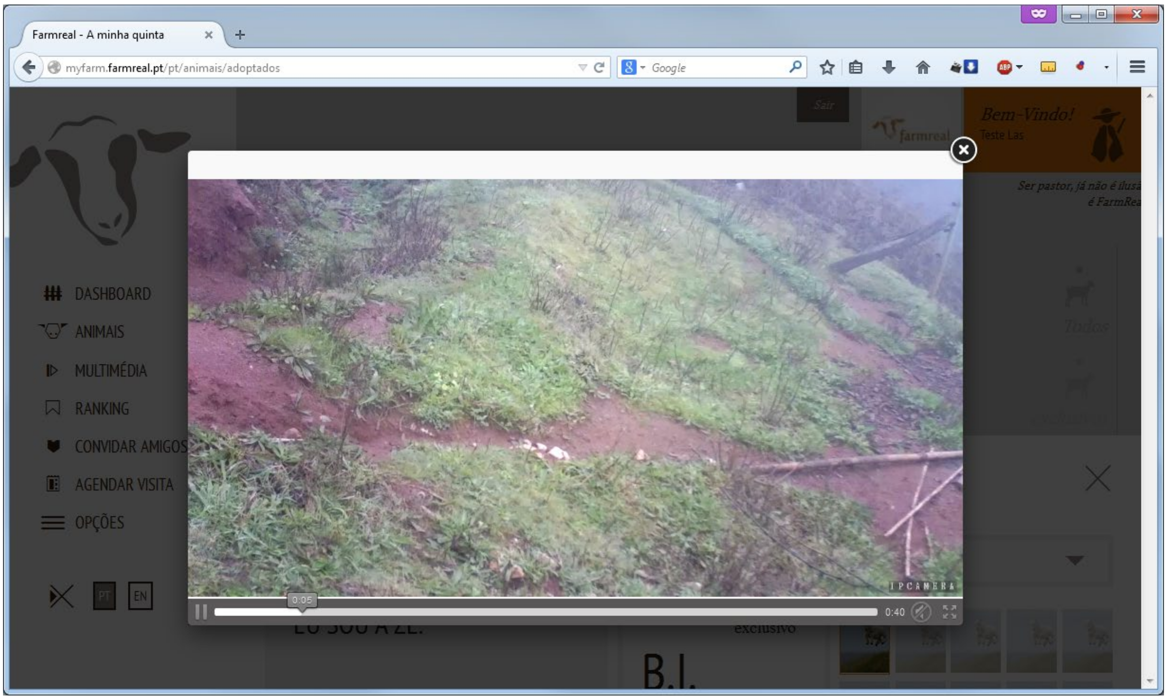


Figure 18– Videos collected by the IP cameras on the platform.

Key Message from the technical validation

The test scenarios were built in order to validate in the field the implementation of all the requirements specified in the initial specifications. With the execution of the test scenarios presented, it was possible to carry out the validation of the system.

In short, it is concluded that the project's objectives were fully achieved, with the development of the proposed system, having reached a high level of maturity, very close to the market.

Community Feedback

For the first testing phase, it was decided to choose 20 testers: 15 *online testers (*to carry out acceptance tests) and 5 *testers* face -to-face (for usability testing).

Of these 15 *testers*, 5 were suggested by members of the Penela City Council and the rest chosen by the Pedro Nunes Institute team, taking into account their age and motivation, from a list of people who signed up by advertising the need for *beta testers* at online platform.

All *beta testers* were contacted via email (with official invitation, see attachment1) and also by telephone.

Acceptance Tests

For the acceptance tests, a testers group was created, *where* daily questions were posed, divided by themes, in order to create constructive discussions between the participants. *Testers.*

The themes were related to each of the menu entries (animals, adopt, *dashboard*, *ranking*, images and videos) and related to conceptual issues, namely values for adoption, types of adoption, themes and ideas .

A questionnaire was prepared with a list of possible *add-ons* , where each of the items was voted from 0 to 5 internally and by each of the *testers*, having in account of its degree of importance. (See Annex 2)

At the end of the questionnaire, there was a formal acknowledgment for the effort of each of the *testers* and the agreement that they would be future users of the platform with benefits.

These tests lasted five weeks and proved to be very enriching, as we were able to obtain a list of *add-ons* that possibly will value the FarmReal platform.

On-site usability tests

The on-site usability tests were carried out at Instituto Pedro Nunes, after working hours, with each of the *testers* and two internal team members.

To start, a video of the project was shown, and then proceeded with a relaxed conversation with some tasks that the *tester* would have to do . These tasks were written and numbered in advance. When it was carried out, one of the internal elements asked some questions related to the *tester* 's attitudes (in order to understand his reasoning), while the other wrote some topics about what was happening. These topics boiled down to:

- Greater difficulties;
- *Testers* ' questions ;
- Time intervals to be performed *tasks* ;
- Other topics relevant to the project;

In Annex 3, you can view the summary of one of the face-to-face tests.

At the end of each face-to-face test, a DOP cheese from the region, an IPN folder with information regarding the Institution and the FarmReal project and a beta *tester* certificate were delivered .

Indirect indicators

The indirect indicators were obtained through the actions of the *testers*, without them being aware of it. A script was implemented that informed the team namely:

- Number of clicks in certain zones;
- hours at which the *testers* usually access ;
- Usage *timestamp* _ by zones;

These revealed which areas of the platform they accessed more often, as well as the preferred times for access. In this way, it was possible to know which areas were most accessed and, for example, the most suitable interval of the day to maintain the platform and insert new data.

Results

After the end of the testing phase, all data were analyzed and discussed internally. Consequently, the main result of this test phase was presented at an internal meeting, the list of possible *add-ons* for the FarmReal platform (as mentioned above, see Annex 2).

Data analysis was performed under the following topics:

1. Concept and acceptance;
2. Interaction;
3. New features;
4. Priorities;
5. Operational conclusions ;
6. Next steps.

In the first point, the functionality of the platform was mainly emphasized as a pedagogical aggregator factor, in which it can:

- Increase contact with the countryside;
- Swap electronics for outdoor activities;
- Publicize and include rural activities (walks with goats, milking, cleaning the corral) and in the holiday period have activities for children.

Ways were also discussed on how to increase the time spent on the platform (more interactivity, possibility of decision-making, real-time visualization of animals and increased accessibility through the availability of applications for IOS and Android); Types of adoption (shared, exclusive and proprietary); Acceptance of locals; Layout acceptance (tips to make it more appealing); between others.

At the point of interaction, the functionalities present on the platform, inside the menus, were evaluated. Here, a list of strengths, weaknesses and ways to improve each of the items was obtained.

Ranking menu, the main results were obtained:

Negative points:

- Poor;
- Little excited;
- Few entries for the *Ranking* ;
- Little informative.

How to improve?

- Trophy animation;
- Podium for the top 3;
- Option of placement on FB;
- *Ranking* exists for the accumulated: average, maximum, minimum, median;
- Placement of *tooltips* or texts explanatory;
- Create game "enter the contest of the goat that gave the most milk in the last month".

From the evaluation of the interaction, the new functionalities emerged. These were reflected in the previously mentioned list, as shown in the following example of new features for the *Dashboard Menu*:

- Disease history;
- Food (available in the pasture);
- Average production;
- Temperament of the animal;
- Annual information (calendar);
- Information regarding maximum, minimum, average and median values;
- Uninformative map (put satellite);
- Real-time positions;
- Possibility of having a *Personal Trainer* to walk with the animal;
- Possibility of giving treats to increase production (food, veterinarian, hair and teeth brushing, collar, painting, cutting, music , etc.);
- Advertising with interaction.

The conclusion and next steps will be exposed in the next point.

Conclusion and next steps

Conducting acceptance tests via the web was quite enriching and productive, even taking into account the risk assumed by the premature exposure of the platform to the web community.

Obviously, not all *testers* could respond promptly to questions asked on Facebook, however adherence was exemplary and they responded as soon as they saw the messages. The *testers* who responded the least were contacted by telephone and they accused the lack of time and malfunctions in the computers. The *testers* who responded the most were the most interested in using the FarmReal platform and, therefore, more committed and enthusiastic about the interaction.

The face-to-face tests took place as planned, having shown that they were extremely important insofar as they confirmed the conclusions of the results of the *online tests*.

The next steps will be the implementation of new features and the new test of the platform, with a greater number of *testers*, grouped per ages. It is also intended to extend the tests to international users.

This testing phase proved to be essential for the good performance of the FarmReal project. In addition, it was an asset to the IPN team, having reinforced its skills in the area of usability and acceptance testing.

Attachments

Annex 1

Email body type sent to online testers:

*Dear **Tester Name**,*
it is with great pleasure that we inform you that we are one of the chosen for beta tester of the platform FarmReal !
*The tests will be carried out on a **date** and to participate you will only have to answer daily questions that we will put in a private group on the social network Facebook.*
Your login to the FarmReal platform will be sent to your email contact, after your acceptance confirmation.
Should any questions arise, do not hesitate to contact us.

Yours sincerely,

FarmReal Team

Confirmation mail body type and data submission with credentials

*Dear **Tester name** !*
Thank you very much for your availability. We've just sent you an invite to join our beta testers group on Facebook.
The credentials to enter in http://farmreal.pt/ are as follows :
Login: xxxPass: xxx
***This login will only work from xxh of the day xx of xxx** .*

Tomorrow we will start posting questions in the group, where your answers will be crucial to improve the platform. Thanks again!

Sincerely,
FarmReal Team

Email body type sent following the telephone contact, to face-to- face beta testers

*Dear **Tester name**!*
Thank you in advance for your cooperation! In the wake of our conversation, I am sending you the information to be able to contribute as a face- to - face beta tester and help us improve the FarmReal

*Your session is scheduled for the **xx of xxx, at xxh , in Building A of Instituto Pedro Nunes** and I will be waiting for you at the entrance.*
The session basically consists of performing some tasks that we are going to ask you

and answering questions about these same tasks.
It won't take more than 1 hour.
Any questions, I will be available to clarify.

Sincerely,
FarmReal Team

Annex 2
Add- on List

LIST OF ADD-ONS
Adopt and Animals Menu
Sex
Weight
Larger and better quality images
Directly age ("has 3 years old")
Hair color and size
mini text
mini video
Being able to name or nickname the goat
"x" to exit windows
Presentation of empathy-creating characteristics
Existence of adoption renewal button
Existence of a buy button
Option to buy cheeses from your animal
All animals (adopted and unadopted) must appear
Ranking menu

Trophy animation
Podium for the first 3 places
FB placement option
Cumulative ranking for average
Cumulative ranking to maximum
Cumulative ranking to minimum
Cumulative ranking for median
Placement of tooltips
Game creation "enter the contest of the goat that gave the most milk"
DashBoard Menu
Disease history
power type
Information regarding average values
Information regarding minimum values
Information regarding median values
Information regarding maximum values
annual information
Satellite imagery for location
instant location
Pampering options (PT, feeding, vet, brushing, collar, earring, painting, cutting)
FB placement option
Online interaction (pigs example) (feature)
Images menu

Increase Thumbnails
Improve image quality
Slide with images (to see that there is continuity)
FB placement option
Image zoom option
Photo ID "day and month"
Videos Menu
more videos short
sound placement
Video of the Day
streaming
Go-Pro on goat
Adoption of a camera
Increase number of Cameras
Others
Amount of combustible material they have already eaten
How many jobs did you get
New menu entry with updates
Amusement park in the Câmara area
Video "Storytelling" outside login
Zone for the dissemination of activities in the area
The adopter is entitled to 1 cheese + 1 site visit per year
alerts per sms

Nature related layout
Add FAQ
Loyalty quiz _
trivia quiz _
adapt to IOS
Suit to android
Add IE9
Placing real images on the homepage
Marketing / Advertising
Online interaction
Stand with a goat
"member get member" campaign
Placing advertising on pasture sites
Rural activities program
prefer to pay more for adoption and your pet is adopted by fewer people (eg 25 people).
prefer to pay any less per adoption and your pet is adopted by more people (eg 50 people).

Annex 3

Example of tester notes from a face-to-face test

FARMREAL
PRESENTIAL TEST (IPN)

This is a person from the Penela region, the main reason for his enrollment is “saudade”.

Introduction menu: not very appealing, very empty (few images).

Small and poor quality images of animals.

Small font size.

Very formal website.

Indicate the sex of the animals.

Activity poorly explained physics .

Milk chart ok.

In the ranking menu, he made an expression of great satisfaction when, when passing with the PC mouse, the animated image changed to a real photo.

Side icons.

location button no he was noticeable .

Software that indicated for tracking the goats : " Runestatic ?"

Option for satellite image, with online GPS location.

Greatly valued the real-time image sound as well as the movie of the day. Possibility to adopt one camera ?

When did you intend come back to the Dashboard had a reaction time as well as an expression of difficulty in navigation.

He considers that goats are funnier, but that from the investment point of view (milk production) he would have tendency to adopt sheep .

Values adoption : 20 € / month

Owner values: buy €200 and then €10 to €15 / month

In terms of payment, do you consider that you would pay without any kind of return knowing that you were supporting the region (saudade and sustainability market)

HOME PAGE
Try remove the scroll

Add more images from Ferraria de São João

TO ADOPT
Larger images

More user-friendly: mini text/video presentation

It's very formal right now

Choice factors for adoption: milk, empathy, whichever proves to be the most profitable

DASHBOARD

Intuitive

Graphs: where the “node” appears, the value of the point on the graph can appear.

Button to change the day is not noticeable (subtitle or change location)

Add annual information (historical): All information!

Calendar (e.g.: runtastic)

add weight

See also satellite map

Option to share information on FB, G+, Twitter

Relate health status to happiness

instant location

Put on a GoPro on goat

RANKING

I would like to have a calendar on the side to be able to view the daily ranking.

More detailed information regarding units of measurement

Being able to click on the trophy and send data to FB

Latest updates tab

A podium with animations with trophies on top of the head

IMAGES

Improve the quality of photos

Larger Images

Did not recognize the landscape of Ferraria São João

don't like the white bar

It would be better to have the identification of the animal

I would like to put on social media, images with quality (without having cut animals)

Possible arrangement of photos:

VIDEOS

Add Live streaming

Add edited videos (where the animals are seen)

Control the image - control movement -> adopt a camera

Add date on video preview

A bar with all the videos (e.g: youtube)

Create a summary of the day

OTHER CONSIDERATIONS

For introduction to rural life: “did you know that”

Field with trivia: lifespan of a goat, number of offspring per season

Made visits daily to FarmReal (more than once a day) to view the images and verify the investment

Changed the image (branding) to create something new (keeping the name and concept)

Profits are important!

Expectation in terms of adoption: sell milk, buy cheese, guarantee return

IMPACT ASSESSMENT

SECTION 05

Impact Overview

Grazing is most effective at treating smaller diameter live fuels that can greatly impact the rate of spread of a fire along with the flame height.

The vegetation or fuel profile, a major factor determining fire behavior, is studied in two aspects: vertical and horizontal arrangement, and amount. The vertical arrangement of fuel determines the degree of its mixture with air and, thus, flame height and duration of elevated heat. The continuity of horizontal fuel arrangement determines potential for fire spread across the landscape. These attributes, along with topography and weather conditions (wind and fuel moisture), are what determine the kind of wildfire that is going to occur. Many management and ecological conditions have allowed for the increased fuels. The increasing number of residences being built in forest and rangeland ecosystems provides more ignition sources and restricts the ability to manage fire. Introduction of exotic plants such as cheatgrass also has changed the fire behavior in many sagebrush plant communities.

Fuel treatments are generally placed in two different categories. Fuel breaks are linear fuel modifications that are often situated along a road or ridge. They can range in width from 30 feet to 400 feet and are designed as a tool for fire fighters to stop fires. Landscape area treatments are designed to reduce flame height and change fire behavior over a large area. Long-term landscape treatment efforts are focused on changing the plant community to decrease the flame height when fire occurs. Both approaches require maintenance in order to remain valuable fire management tools. The objective for fuel reduction is to change fire behavior by impacting the following: fuel bed depth, fuel loading, percent cover, and ladder fuels that result in a fire flame less than four feet high. At that level all firefighting management tools can be used, while maintaining fire fighter safety.

Mechanized Treatments

Mechanized treatments are used by land managers to alter or remove vegetation, including mowing, mastication, and biomass harvesting. Mastication involves the use of a large mechanized device for chopping, and is used in brush and trees to break up the fuel pattern and decrease combustibility by placing fuels on the ground. It changes fire behavior by rearranging the fuel profile through distributing some of the fuel on the ground. This action also causes a reduction of ladder fuels, which decreases potential for vertical extension of fire into tree canopies; crown fires are very difficult for fire fighters to control. Mastication can be used as a pretreatment followed by prescribed fire or grazing treatments. Some of the disadvantages of mastication are the cost of 350€ to 800€ per acre, ground disturbance, short life of the treatment in some areas, terrain and surface roughness limitations, and soil compaction. Mastication can result in death in some brush species, but many species resprout from the roots and require retreatment.

Mechanized treatments also include the thinning of overstory vegetation through biomass harvesting. The harvested biomass is brought to a chipping unit and the resulting material is transported off the site for use in energy power plants. The sale of the biomass chips reduces the cost of this treatment. Thinning can provide desired conditions for both ladder fuels and crown spacing in one treatment. Soil moisture condition is the only limitation on the time of year that the treatment can be conducted. Disadvantages include transportation costs of hauling biomass and removal of nutrients from the ecosystem. In some cases, trees that are removed can be sold as commercial saw logs to offset fuel treatment costs. Mowing is generally used in grass communities to drop the fuel on the ground, where it has less contact with air and thus has lower combustibility. Mowing needs to be done during the end of the green season or it can cause fires from the blades striking rocks when dry grass is present. The costs of mowing range from 25€ to 40€ per acre.

Herbicides

Herbicides can be sprayed to kill specific plants, but this does not alter the fuel pattern immediately. Herbicide treatment of targeted species has a cost of 25€ to 250€ per acre. The disadvantages include concerns about its impact on the environment and short-term increases in fuel flammability.

Prescribed Fire

Prescribed fire can be used to change the fuel load and pattern. Prescribed burning can generally be achieved for less than 150€ per acre. It is most effective for reducing surface fuels 0–3 inches in stem diameter. Because of air quality concerns and the need for the correct fire weather conditions (wind, air, and plant humidity), there is usually a narrow time period in the season during which burning can be done. A mechanical or hand removal treatment might also be required prior to the reintroduction of fire into the ecosystem to achieve desired fire behavior. The disadvantages of this treatment are reduced aesthetics, tree mortality, impaired air quality, liability concerns, pretreat- ment costs where applicable, the requirement of qualified people who understand prescribed fire, and treatment varia- tion (it might burn hotter or cooler than planned). Also, it might not be appropriate for some plant communities, such as low-elevation sagebrush, which can be replaced postfire by cheatgrass.

Hand Cutting

Hand cutting and stacking of fuels for burning is very labor-intensive and thus expensive. Costs range from 800€ to 2,300€ per acre, depending on amount of vegetation. It is the best alternative on steep slopes where mechanized equipment cannot operate.

Grazing

Grazing is best used when addressing the smaller diameter vegetation that makes up the 1- and 10-hour fuels. One- hour fuels are those fuels whose moisture content reaches equilibrium with the surrounding atmosphere within 1 hour and whose stems are less than one-fourth inch in stem diameter. Ten-hour fuels have stems that range from one-fourth inch to 1 inch in stem diameter. Grazing can impact the amount and arrangement of these fuels by ingestion or trampling. It is a complex, dynamic tool with many plant and animal variables, and it requires sufficient knowledge of the critical control points to reach treatment objectives. Those control points involve the species of livestock grazed (cattle, sheep, goats, or a combination); the animals' previous grazing experience (which can affect their preferences for certain plants); time of year as it relates to plant physiology (animal consumption is directed by the seasonal nutrient content); animal concentration or stocking density during grazing; grazing duration; plant secondary com- pounds; and animal physiological state. Treatments either can be short-term to reduce flammable vegetation or long- term to change vegetation composition by depleting root carbohydrates in perennials and reducing the soil seed bank for annual plants. The objectives are to change the fire behavior through modification of the fuel bed, fuel loading, percent cover, and ladder fuels.

Depending on the plant community, the vegetation of concern or fuel will differ. The grazing approach to fuel treatment differs with the plant life cycle (annual or perennial). With annuals, the treatment is to remove plants while they are still green each year prior to fire season. Grazing before seed set can change seedbed dynamics, and with long-term implementation, grazing can change the species composition. For perennials, repeated grazing that depletes root carbohydrates and causes morality of targeted species is required to change plant composition. Root carbohydrate reserves are at their lowest level just after the period when plants initiate active shoot elongation. If plants are severely grazed early in the growing season, carbohydrate reserves are depleted, and plant vigor is reduced. Removal of bark or repeated defoliation are two other ways to destroy the plant. In brush species, the concept of changing the fuel profile the first year and managing it thereafter with grazing over large areas appears to be most sustainable.

Integration of different treatments could provide the best strategy. Livestock cannot effectively control mature brush plants that either grow higher than the animals can effectively graze or have large diameter limbs. Mastication, underburning, and hand-cutting can be used to manipulate the large-diameter, 100-hour brush fuels, and grazing can be used as a follow up treatment for controlling resprouting species or shifting the species composition to herbaceous plant fuel material. Tsiouvaras suggests that grazing followed by prescribed fire can be used safely to kill the aboveground parts of shrubs and further open the stand. Magadlela reported that adding cutting and herbicide use increased sheep effectiveness by reducing the brush below 20% in one year, but increased the costs.

Prescribed grazing has the potential to be an ecologically and economically sustainable management tool for reduction of fuel loads. However, much of the information on grazing for fuel reduction is anecdotal. Limited scientific research information is available. Existing data indicate there are two ways by which grazing impacts the fuel load: removal of vegetation, and hoof incorporation of fine fuels. Smith et al. found that

350 sheep (ewes) grazing intensely on sagebrush/cheatgrass in a 2.5-mile fuel break (divided into 20 pastures) in May in Nevada reduced fine fuels from 2,622 to 765 pounds per acre. Vegetative ground cover decreased 28% to 30%, ground litter increased 20% to 23%, and bare ground increased 4%. Tsiouvaras studied grazing on a fuel break in a California Monterey pine and eucalyptus forest in the fall at a stocking rate of 113 Spanish goats per acre for 3 days; brush understory was reduced by 46% and 82% at 20 inches and 59 inches in height, respectively. Forage biomass utilization in the brush understory was 84%. California blackberry showed the largest decrease in cover (73.5%) followed by toyon, coyote brush, honeysuckle, herbaceous plants, and madrone. Poison oak and eucalyptus exhibited very little change. Goat grazing not only broke up the sequence of live fuels (horizontally and vertically up to 59 inches), but also reduced the amount of 1-hour dead fuels by 58.3%, whereas the 100-hour fuels remained constant. The litter depth was also reduced as much as 27.4% (from 2.9 inches before to 2 inches after grazing). Animal trampling resulted in crushing of fine fuels and mixing them into the mineral soil, thus reducing the chance of ignition. Green et al. grazed 400 goats on chaparral in July.7 The goats utilized 95% of the leaves and small twigs to 0.063 inches diameter from all the mountain mahogany plants. Use of scrub oak was 80%, whereas use of chamise, eastwood manzanita, and California buckwheat was low, and Ceanothus was only taken under duress. Under “holding pen” conditions, use of less palatable species approached the use of palatable plants. Lindler reported that goats stocked at 7 per acre for 3 weeks in the summer in a ponderosa pine forest were estimated to remove 15% to 25% of the vegetation, depending on the plant species present and the length of stay in the pasture. The cost of the grazing treatment was 60€ to 70€ per acre. In comparison, herbicide costs on adjacent sites were 60€ to 125€ per acre, and 75% to 90% of the vegetation understory in the pine forest was removed. Intensive grazing by cattle to control shrub growth has been demonstrated as being useful for maintenance of fuel breaks. Perevolotsky et al. found that mechanical shrub removal and cattle grazing at the peak of green season in Israel 4 years in a row proved to be the most effective firebreak treatment. Heavy grazing for a short duration removed more than 80% of the herbaceous biomass, but reduced regeneration rate of shrubs for only 2 years. They stated that using goats or other browsing animals can increase the amount of shrub material removed by direct grazing, but can decrease actual physical damage to shrubs (cattle will trample and break more brush and graze less due to their size, whereas the opposite is true for goats). Henkin et al. found that under heavy grazing (71–83 cow grazing days per acre), the basal regrowth of the oaks was closely cropped and the vegetation was maintained as predominantly open woodland. In the paddock that was grazed more moderately (49–60 cow grazing days per acre), the vegetation tended to return to dense thicket.

Each species of animal has a unique grazing utilization pattern that is a function of mouth size and design, past grazing experience, and optimization of nutritional needs. The mouth size controls how closely animals are able to select and then graze a given surface. Animals also differ in their forage preferences and diet composition, thus when developing a fuel reduction grazing program, it is important to select the kind of livestock that will consume the desired species to alter the fire behavior. Provenza and Malechek showed a 50% reduction of tannin in goat-masticated samples compared to unmasticated samples. This illustrates that goats can affect one of the secondary compounds that are present in some brush species, and thus can eat more of that species. When preferred forage is absent or unpalatable, grazing animals are capable of changing their food habitat.

Table 1. Percent of time spent by animals feeding on diverse plant types in Penela

Forage type	Animal species		
	Cattle	Sheep	Goats
Grass	78	53	50
Forbs	21	24	29
Browse	1	23	21

Magadlela et al. found that goats grazing in Appalachian brush defoliated brush early and then grazed herbaceous material later in the seasons. Sheep preferred to graze herbaceous material first, but increased grazing pressure forced sheep to defoliate brush earlier in the season. Goats reduced brush cover from 45% to 15% in one year. Sheep took 3 years to produce the same results. Brush clearing improved when goats followed sheep; total brush was reduced from 41% to 8% in one year. By the end of 5 years of goat grazing, the brush was reduced to 2% cover. Luginbuhl et al. found that multiflora rose was nearly eliminated from the Appalachian Mountains after 4 years of grazing by goats alone (100%) or goats+cattle (92%). Simultaneously, total vegetative cover increased with goats alone (65% to 86%) and with goats+cattle (65% to 80%), compared with the control plot where vegetation cover decreased from 70% to 22%. Lombardi et al. studied the use of horses, cattle, and sheep in Northwest Italy for 5 years and found that grazing reduced woody species cover and stopped the expansion of shrub population.19 The impact varied with the type of animal. Cattle and horses had a higher impact on the plants through the damage caused by trampling. It was found that the effectiveness of control depended on palatability and tolerance of woody species to repeated disturbance. Juniper and rhododendron were reported not to have been grazed. Hadar et al. reported that the inconsistent response of some plants to grazing could be the interaction between grazing pressure and moisture conditions. They found that heavy cattle grazing (340–394 cow grazing days per acre) during 7 to 14 days at the end of the growing season decreased species richness because of consumption of seeds from the annual plants.

The time of the year that grazing occurs can influence the types of plants consumed, because it impacts the plant physiological status, which controls the nutritional value to the animal. Additionally, the time of year affects the plant's postgrazing mortality. Taylor reported studies using heavy grazing by sheep in Idaho showed that season of use impacted the utilization. Late-fall grazing reduced three-tip sagebrush, whereas grazing during spring increased sagebrush and decreased grasses.

Grazing impact can change with the density of animals and duration of grazing. The shorter the duration, the more even the plain of nutrition is. Over longer periods in a pasture, animals select the most nutritious forage first and consume less nutritious forage later. Stocking density has a great impact on the grazing consumption and tram-pling of fuels. Fences, herding, topography, slope, aspect, distance from water, placement of salt, and forage density all impact the distribution of animals and their use of the forage. By concentrating the animals into a smaller area for short periods of time, the preference for plants decreases and animals compete for the available forage. Increasing stocking density also increases hoof action and incorporation of the fine fuels into the ground. Spurlock et al. stated that high stocking rates with little supplementation forces goats to graze even less palatable species and plant parts, and as a result, much brush can be eradicated in 2–3 years.

Table 2. Sheep diet consumption in Penela variedwith stocking rate

Stocking rate	Forage type		
	Browse	Grass	Forbs
Light	16	55	28
Heavy	55	39	5

Table 3. Results with sagebrush/grass pastures grazed at different intensities by sheep in Penela

Grazing intensity	Baresoil	Vegetationcover (%)	Litter
Light	+6	-22	+25
Moderate	+4	-28	+20
Heavy	+4	-30	+23

Hadar et al. reported that light grazing increased plant diversity on treated sites. Thus, when proposing a stocking rate for treatment consumption, the environmental impact needs to be considered.

Plants, over time, have developed mechanisms to limit or prohibit grazing. Launchbaugh et al. summarized this plant and animal interaction as follows: plants possess a wide variety of compounds and growth forms that are termed “anti-quality” factors because they reduce forage’s digestible nutrients and energy or yield a toxic effect that deters grazing.22 Secondary compounds (eg, tannins, alkaloids, oxalates, terpenes) can control the plant–animal inter- actions that drive intake and selection.

Animals might expel toxic plant material quickly after ingestion, secrete sub- stances in the mouth or gut to render the compounds inert, or rely on the rumen microbes or the body to detoxify them. The species of livestock selected is important because some species can detoxify compounds or have a smaller mouth that allows them to eat around thorns; this allows them to still obtain nutritional or pharmaceutical products that aid in digestion and detoxification. Breeders can select for animal genetic lines that can adapt to these compounds. Tannins are the most important plant defensive compounds present in browse, shrubs, and legume forages. Concentrations in woody species vary with environment, season, plant developmental phase, plant physiological age, and plant part. In some cases, when the plant compound is known, it is possible to intercede. For example, polyethylene glycol (PEG), a polymer that binds tannins irreversibly, can be used to reduce the negative effects of tannins on food intake, digestibility, and preferences. For oxalates, calcium supplementation has shown to ameliorate the diet suppression. Launchbaugh et al. suggests that supplementation of protein, phosphorous, sulfur, and energy can also make a difference in intake of plant material containing secondary compounds.

Grazing animals can effectively distinguish between plants that differ in digestible energy or nutrients. The animal's consumption is driven by its physiological state. Nonlactating animals have much lower nutrient requirements than lactating females or growing weaned animals and can consume a wider array of plants to meet nutritional needs. Animals can be forced to eat below their nutritional needs and they will balance their needs by using existing body fat and protein. The animal can tolerate short-term energy or protein deficits, but sustained periods at this status can be reason for concern. For this reason, lactating and young growing animals are not generally recommended for fire fuel control. In a system that is focused on maintaining the fuel profile, one can use growing animals in an annual brush grazing system that focuses on the annual new growth.

Because of the complexity of plant and animal interactions, a project evaluation should be developed that considers measurable and attainable objectives before grazing is used. It should include a review of treatment objectives, outcomes, and environmental impacts. This will dictate the kind of animal needed, grazing intensity, timing of the grazing event, and duration of the grazing period. Variation in animal–plant interaction is driven by forage type, grazing season, yearly season variation, animal interaction with the grazing system (animal density and competition), previous grazing experience, mixture of grazing animals, and pregrazing treatment (integrated approach). The treatment and resulting outcomes cannot conveniently be predicted and might require adaptive onsite management. Treatment standards include stubble height for grass, percent vegetation cover by brush, plant mortality, removal of 1- and 10-hour fuel, and fuel bed depth.

Any grazing plan designed for fuel reduction needs to consider the grazing impacts on parameters other than just simply reduction. The effects of the grazing management should be studied for their impact on water quality, com- paction, riparian vegetation, disease interaction with wildlife (bluetongue, pasturella), and weed transmission. The positive aspects of grazing over other treatments also should be weighed, including recycling of nutrients into the products of food and fiber.

Grazing is best used when addressing vegetation with stems of smaller diameters that make up the 1- and 10-hour fuels. These two fuel classes are important because they can greatly impact the rate of spread of a fire, as well as flame height. Many fire managers have viewed grazing in the same context as other single-event mechanical fuel treatments.

These grazing treatments have been expensive to implement because they have a physiological cost to the animal, and require higher costs (such as portable fencing) to reach fuel objectives in one year. Perhaps a sustainable use of grazing would be annual grazing of large areas following mechanical treatment. This provides improved nutrition by presenting smaller regrowth that is higher in nutrition; this allows animal performance to improve while maintaining a specific fuel profile in the grazing area.

There are many issues that need to be considered when examining grazing for fuel reduction. Grazing has a more varied outcome than the mechanical fuel reduction treatments. Until the grazing treatment is perfected into a fully understood tool, the dominant management strategy will be to force utilization by limiting nutrition and/or preference. There is a lack of scientific data available to help managers understand and control the many variables that influence the outcome of fuel removal, and thus reaching defined objectives will be more difficult. The objectives of the treatment must be well-defined and well-described. It is important to understand animal preference as well as proper timing in order to meet the objectives. Some have considered fuel reduction by grazing simply as a method to increase animals on public lands; thus a well-thought-out plan is important. Many do not trust agencies to administer a private sector contractor to conduct the treatment correctly; thus a contract needs to be well-defined within the parameters of the operator's control. In the past, fire managers were willing only to look at the short-term impacts and not the long-term health and fire safety of the site or the effects of a long-term grazing program. Consumptive use, such as grazing, might not be compatible with recreation land use in some areas. A survey by Smith et al. indicated that 90% of residents near a fuel break stated use of sheep was an acceptable method for fuel reduction. Only 10% felt that they were inconvenienced by the treatment. Some responses indicated misconceptions held by residents regarding grazing and grazing management methods; one such example was fear of possible electrocution of animals and humans by electric fences. These misconceptions by the public must be addressed when land managers make proposals for grazing.

Conclusions

Modification of wildfire fuels is an important issue in many regions of the world. At present, limited research knowledge exists to help guide managers in using grazing animals for fuel management. That knowledge is necessary to direct the timing and intensity of grazing to reach fuel management objectives similar to other methods. Also, seasonal variation of nutrition content and secondary compounds of shrubs need to be further defined. Most of the grazing fuel modification study work has been conducted with goats, primarily because of their preference for targeted plant species. Grazing animals can modify wildfire fuels through consumption and trampling. Animals are most effective at treating smaller-sized live fuels and 1- and 10-hour fuels. These fuels influence an important part of fire behavior by providing the flammable material that creates a ladder of fuel in order for a fire to extend up from the ground into the brush and tree canopy. There is a lack of research knowledge upon which to draw in order to refine the grazing treatment to meet fuel management objectives. Many treatments in the past had only a single grazing year focus. This strategy can be effective in a grass ecosystem if timed right, but systems with abundant shrubs often require multiple years to create and maintain a fuel profile that is more desirable.

More research needs to be done to allow effective use of grazing as a fuel reduction tool. Further research also needs to be done on secondary compounds in brush plants, their seasonal variation, and methods to overcome them to achieve target utilization levels. Knowledge of the nutrient status of the plants throughout the year also will assist in indicating the time of optimum utilization of grazing in fire fuel reduction.

Goat grazing strongly can reduce both native and non-native herbaceous cover and height, which may be desirable in areas where flashy fuels and ignition risk are a concern. It is important to note that goats also removed most of the non-natives on the landscape (87% reduction). Land managers interested in using goats to control undesirable non-native species should take into account the phenology and palatability of the target non-native species.

Although goats can successfully reduce herbaceous biomass, the reduction of woody biomass is often one of the most important goals for fuel management in chaparral ecosystems. Goats will eat a wide variety of species compared to most livestock but can be selective in targeting plants that are in a favorable growth stage, depending on the duration of grazing (Bashan & Bar-Massada 2017; Green and Newell 1982). Goats behave as browsers in Mediterranean landscapes (Bartolome et al. 1998) and have been shown to successfully reduce woody and herbaceous cover (Gabay et al. 2011). Intense goat grazing applied during several periods throughout the growing season not only prevents woody regeneration but has been shown to significantly decrease woody cover (Bashan & Bar-Massada 2017). The Lake Morena study examines short-duration goat grazing and shows that although goats were successful at reducing herbaceous cover, longer-duration grazing is likely necessary for woody biomass reduction. Due to the selectivity of goats in targeting woody plants, land managers should consider the seasonality, stage of regrowth, and species composition when deciding whether goats are an appropriate tool for fuel break maintenance (Bartolome et al. 1998).

GAP ANALYSIS IN FUEL AND WILDFIRE RISK MANAGEMENT PROGRAMS

Interviews description and profile

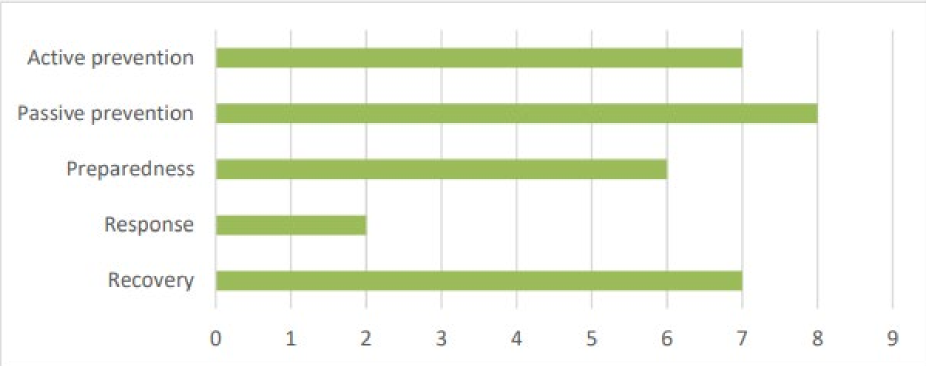
Eight interviews (Integrated Fire Management S.A. – GIFF, Nature and Forest Conservation Institute – ICNF, Flocks of Serra do Açor and Rabadão, Reserva Faia Brava, Terra Chã Cooperative, SILVPAST Operational Group, Forest Management – ACHLI, Rede Energética Nacional – REN) have been done linked with fuel management programs and wildfire risk management actions. Six of them are private initiatives or institutions while two are public. Three interviews were done to institutions, four to initiatives, and one is related to both.

Among the institutions interviewed, there is a public institute aimed at defining and implementing national forest policies, providing guidelines and strategies to implement fuel management, forest fire defense plans, fire statistics, etc. This institute works also in all the DRM cycle phases. A second institution is a private cooperative providing wildfire prevention and management services through grazing. Finally, the third is a private company in charge of the national energy network, which also reduces fuel loads under electric lines. Regarding the four initiatives, there is a private initiative that rents communal land to raise goats and to produce dairy products, in order to maintain the primary firebreaks network. Another private initiative promotes fuel reduction by grazing with semi-wild herbivores in natural reserve Faia Brava in central Portugal. Both are acting in Prevention, Preparedness and Recovery phases. A third one acting in Passive prevention is an initiative related to an Interreg SUDOE project, which tests and develops a method for the implementation of silvo-pastoral mosaics using remote sensing approaches that supports agricultural and forestry activities in forests of Pyrenean oak, which typically have low agricultural value. Finally, a forest management project initiative aims at improving and manage forest lands as a measure for wolf conservation, including wildfire prevention. This forest management is basically promoted by Passive prevention actions, such as the maintenance of mosaic landscape and grazing, and other structural support to rural development. Finally, there is a private company that is both initiative and institution, which acts in all the DRM cycle phases and provides forest fire prevention and suppression services. This company is related to resin exploitation in Pinus pinaster forests in communal land areas.

Type of fuel management programs Among the interviews, the most represented fuel management program is linked with the Other category, which was selected in six interviews (all the interviews except Operational Group SILVPAST and National Energy Network, Graphic 12). The second category most represented is the RDP measures, which is related to the wildfire prevention measures or actions co-funded. This category was four times selected among all interviews and includes (i) the public Nature and Forest Conservation Institute (in charge of managing the calls for public funding), (ii) the private initiative of Serra do Açor e Rabadão flocks, (iii) the private cooperative Terra Chã and (iv) the SILVPAST Operational Group, which are beneficiaries of specific RDP measures. Local initiative category was selected by the Nature and Forest Conservation

Institute and the flock's private initiative Serra do Açor e Rabadão. Normative compliance was two times marked by (i) the National Energy Network (REN) that is responsible of managing the fuel in the forest areas previously defined in the Municipal Plans for the Defence Against Forest Fires (PMDFCI), and (ii) the Nature and Forest Conservation Institute which is responsible for defining and implementing national forest policies. Finally, EU project category was selected by only one interview: Faia Brava natural reserve, where an EU project was developed.

The eight interviews are mainly related to wildfire prevention through Active and Passive prevention. Concretively, the public institute of forest and nature conservation and the private company that provides forest management services covers the whole DRM cycle phase. All the initiatives and institutions interviewed are linked with the Prevention phase. There are also some initiatives linked with Preparedness and Recovery phases.



Gap analysis

• Which are the contributions of the actions to wildfire prevention?

The contributions are mainly related to activities directly linked to the objective of mitigating wildfire risk. Moreover, other territorial activities indirectly contribute to the reduction of risk, even if that is not the main objective. The main specific contributions are:

- Support to forest activities (non-wood products) that indirectly contributes to wildfire prevention. - Promotion of different programs related to wildfire prevention such as: forest sappers, control and technical monitoring of burnings, strategic fuel management land mosaics within forest fires defence network, fuel management by livestock, resin extraction and fuel management according to law requirements.

- Contribution to decrease land abandonment and the corresponding increase in fuels, which indirectly results in less fire risk.

- Fuel reduction treatments by mechanical works or grazing.

- Environmental education actions.

- Experimental areas for reforestation after a fire.

- Cleaning the watercourses as a wildfire prevention infrastructure.

- Combine forest management actions with nature conservation, especially regarding wildlife.

• Which are the limitations of the actions?

The limitations are mainly linked with the lack of funds and available budget to do the actions designed. Thus, there is a higher territorial demand than the financial capacity to cover it. Furthermore, it is also identified that there is a lack of human resources to cover the needs (from administrative technicians to forest workers). In this sense, interviewees highlighted that the funds are inadequate, and the payments are not adjusted to the needs, thus, sometimes the calls are not well structured since the payments are reimbursed, which implies a lack of available money in advance. A second limitation that was highlighted was the excess of bureaucracy to develop prevention actions (both, access to funds and to do forest works). An interesting point mentioned was the specific excess of bureaucracy to implement prescribed burning activities and how consequently the practice is not "attractive". A third important limitation mentioned was the low business profitability and the low market value of some activities (e.g., grazing, resin and forest extraction, etc.), which makes these practices economically non-feasible. This could be also linked to some terrain conditions (steep slopes, difficult accesses, etc.), which may constrain forest activities and increase the costs of fuel management. Other less common limitations mentioned were the lack of long-term vision of some local administrations, which do not support some wildfire prevention actions, such as grazing, since there are no short-term results. This is a structural issue linked with "politic timings", which generally influence the territorial model applied (e.g., support to activities with short-term profitability, such as tourism). The difficulties to find people to develop forest work was also a highlighted limitation since aged population is not able to do forest works and younger population, is generally not interested in this kind of work (even if payments are higher than the national minimum salary).

• How to enhance the contributions of the actions towards wildfire prevention?

The main points raised were related to:

- Foster and promote forest products and livestock as a natural, local and sustainable production, highlighting the added value that they have for the maintenance of the territory.

- Making changes in the RDP model to better recognise the contribution of some activities to wildfire prevention, including specific criteria of selection.

- Promoting and increasing the revitalization of local economies and the development of marginal territories, either through ecotourism, recreational activities or new business models. - Including the fuel treated areas that became resilient to wildfire, as a support infrastructure for the Fire Service in case of wildfire (response phase). An interesting point highlights the possibility to develop schemes of payments for ecosystem services (wildfire prevention service) since some activities on the territory are contributing to decrease wildfire risk while enhancing and managing biodiversity and priority habitats quality. Finally, a contribution linked with communication and dissemination actions was mentioned: the dissemination of lessons learnt to replicate useful tools and methods.

• **Do you know good initiatives/best practices linked with wildfire prevention and management?**

Are these initiatives funded by specific programs, or could they be funded? Some of the interviewees mentioned the following initiatives:

- National Electric Network fuel breaks under electric lines in agreement with landowners.

- Operational Group SILVPAST: Promoting grazing for wildfire prevention

- Open2preserve project: Promoting Forest management for wildfire prevention and biodiversity conservation.

- Rainfed agriculture (olive groves) around the villages and funded by some Portuguese municipalities.

- R&D Project "Alvares: a case of fire resilience": Started after the severe 2017 fire. The main objective of the study was to propose a set of measures for planning and intensifying forest management, aiming at the future "construction" of a landscape in Alvares less vulnerable to fires. The measures proposed were designed lower the frequency of large fires, to create safer parishes and to improve the local economy, particularly forest profitability of private landowners.

- Project MAQQ: Support mechanism for burning debris and scrubland. The objective is to provide technical support to the community and their burning activities.

- Quinta Lógica (Sistelo): Development project for sustainable management of ecosystems and fire prevention. Within the World Biosphere Reserve Gerês-Xurés (UNESCO), located in the parish of Sistelo, municipality of Arcos de Valdevez, this initiative uses a flock of native goats in extensive grazing and invites people, including people living in the city, to get involved in landscape management, to adopt a goat and to follow the life of the herd from a distance or by visiting the herd.

- Terra Maronesa (Alvão) initiative: A practical community that intends to enhance the habitat of the native "Maronesa" bovine breed, based on a holistic and systemic approach. It also aims to enhance the vast food heritage in its different economic, cultural, social, environmental and touristic aspects.

- Rebanho Casal Novo e Cepos (Arganil): Flock of 150 sapper goats that started after the 2017 fires. Funded by a special fund created after the 2017 fires in Portugal (Fundo Recomeçar, Santa Casa da Misericórdia de Lisboa) and partnered by the Escola Superior Agrária de Coimbra (ESAC – Coimbra Agricultural College). Since this initiative is not focused on production, it is very dependent on funding to keep the activity development.

- Rewilding Portugal: Progressive approach to conservation. The main objective is to let nature take care of itself, enabling natural processes to shape land and sea, repair damaged ecosystems and restore degraded landscapes.

Using FarmReal to attract tourists and consumers:

One of the added values that FarmReal shows is the fact we can customize the platform regarding the interests of Ferraria São João. After talking with the community, it was concluded that FarmReal should not only be used as a fire prevention tool but as also a platform to showcase the best activities and products available in Ferraria São João. So, FarmReal will include activities for users to buy such as cheese making workshops, rural tourism, etc. In long-term, FarmReal platform can support Ferraria São João in:

• Provides employment opportunity – rural areas are characterized by low employment providing regions. The key characteristic of such regions is that there is a very minimal scope of employment opportunities in such areas. Since employment has been troubling the government for the last few years, rural tourism could prove to be an opportunity for overcoming the gap in employment avenues. Government schemes such as a scheme for Promotion of Innovation, Rural Industry and Entrepreneurship, Scheme for Skill Strengthening for Industrial Value Enhancement are some of the schemes and initiatives which if applied to the rural tourism industry could result in beneficial outputs.

• Provides alternative sources of income – Rural people are majorly dependent on farming and nonfarming activities for their livelihood. Rural tourism, therefore, could prove to be an alternative for livelihood sources. Government scheme of Skill acquisition and Knowledge Awareness for Livelihood promotion aims at increasing the earning capacity of people could be used for imparting required knowledge to the stakeholders.

• Balanced regional economic development – Development of rural tourism could be a stepping stone for the regions that lack resources to develop themselves economically and socially. Since development through the manufacturing sector is not possible in the absence of resources like raw materials, rural tourism can be used as an alternate industry to develop rural regions.

• Means for social inclusion – FarmReal can also be used as a mechanism for making people aware of the local customs and traditions of a place. Alternatively, it can also be used as a mechanism to teach locals about the lifestyle of the population at large living outside their habitual zone. People from the urban background who are unaware of the diverse culture by visiting rural regions will get to experience the culture in fairs and exhibitions. Learning by experiencing will be much more fruitful in promoting social inclusion.

MAIN CONCLUSIONS

SECTION 06

Wildfires are one of the most prominent risks for Mediterranean forests, reducing the flow of ecosystem services and representing a hazard for infrastructure and human lives. Several wildfire prevention programs in southern Europe are currently incorporating extensive livestock grazers in fire prevention activities to reduce the high costs of mechanical clearance.
The threat of large forest fires is increasing, and the main causes are the depopulation of rural areas, along with the effects of climate change. To counter this threat in recent decades, there have been numerous proposals and actions aimed at promoting grazing in the forest as a tool for controlling biomass fuel. However, the continued disappearance of traditional herds makes this activity difficult. In this work, an analysis is made on the effect of goat grazing on the control of the vegetation in firebreak areas. The results showed that these areas in themselves exert an attractive effect with respect to the neighboring forest, and that the herbaceous biomass is reduced. In general, it was possible to reduce the phytovolume of many species without affecting biodiversity in the short or medium term. Therefore, strategic management of goats, aimed at firebreak areas, could contribute not only to reducing the risk of fires and, consequently, to the mitigation of climate change, but also to attracting these animals to the forests, thus avoiding their dispersion to conflictive places such as roads, residences, agricultural fields, and gardens.

Strength points of goats use in fire prevention:

- Can profitably convert brush and weeds into a salable product
- Can be grazed with other species including cattle, sheep, or horses in a co-species grazing system
- Difference in diet preference makes these classes of livestock compatible and complementary
- Internal parasites are reduced when cattle or horses graze with goats
- Livestock losses from poisonous plants are reduced by co-species grazing
- Capable of defoliating most plants species, many of which cattle will not utilize
- While eating undesirable plants they produce a salable product (milk)
- Preferentially consume seeding stems, reducing the spread and perpetuation of weeds by seed
- Ticks and snakes are reduced due to reduction of their habitat
- Opportunistic generalists, they tend to consume the most palatable available vegetation
- Very flexible in their dietary habits, able to adjust to a diet change
- Able to select the most nutritious available components of biomass, regardless of type
- Tolerate higher levels of tannins than cattle or sheep
- In most cases, goats are the most cost-effective, nontoxic, non polluting solution available

FarmReal aims to improve the uptake of digital technologies in goat farming and grazing. FarmReal was partnering with Ferraria São João during a pilot programme. This report presents the major studies carried out together with the community of Ferraria de São João. Tapping into an old agricultural practice, the herds are set out to graze in strategic areas of the forest identified as being at risk from fires.

The local goats, particularly suited to the terrain, make quick work of munching through overgrown trees and scrubland vegetation. This not only deprives fires of fuel, but also creates cleared areas for fire crews to easily reach the forest. It's simple, cheap and effective, and also gives the shepherds a unique selling point for their products.

Thank You

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