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Development Engineering 5 (2020) 100050

Contents lists available at ScienceDirect

Development Engineering

journal homepage: http://www.elsevier.com/locate/deveng

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ARTICLE INFO

Keywords:
High-land family farming
Appropriate machines
Intermediate machines
Open source machines
Rural areas

ABSTRACT

The article analyzes the role of appropriate technologies for mechanization and innovation in small-scale farming in the mountainous and hilly areas of Italy's Piedmont region.

Our approach to appropriate technologies focuses on mountain farmers whose needs have not been met by advances in agricultural mechanization, which have largely served the interests of lowland agribusiness. Mountain farmers' technological needs were determined using a specific methodology based on an in-depth analysis of the reference target and a field work using an open and inclusive process. The needs thus identified served as the starting point for designing appropriate and intermediate machines. In the conclusions, we present some general implications of appropriate technologies in terms of co-design for development.

1. Introduction

The paper presents the results of a participatory fieldwork aimed to design and develop appropriate machinery for mountain agriculture. We maintain that mountain agriculture generates forms of "micro-innovation" that are developed and used to solve *practical* problems encountered in the *daily* management of the production process. They are thus not very visible outside the organizational boundaries of the farm, since they often do not follow an immediate market principle and tend to involve skill-oriented and site-specific technologies (Ploeg, 2018). Micro-innovations contribute significantly to the production of positive externalities, increasing the added value not only of the single farm but of the entire value-chain. These innovations are strongly place-based and relocate the value generated in the same place that produced it. As we will argue in the following, micro-innovations require a user-centered approach able to highlight the key role of *co-design for development*. These principles, in turn, require to set inclusive place-based mechanisms able to empower the "capability for voice" of marginal actors and left-behind areas (Rodríguez-Pose, 2017). To this end, after outlining the geographical setting and the analytical framework of the research, we shall illustrate the methodology adopted and the needs emerging from our analysis. We shall then describe several machinery concepts, design and prototypes, developed by us, in order to validate the design methodology and provide some examples of appropriate technologies for mountain agriculture. In the conclusion, we will summarize the paper with regard to the utility and applicability of the method to the farmers in mountain regions of Italy, as well as its general applicability to co-design for development.

2. The role of mountain agriculture worldwide and in Italy

In 53 countries of the world, mountainous areas cover more than 50% of the national surface area. In another 46, they cover between 25% and 50%, and in many other countries they play key roles, such as serving as a water reserve, even though the proportion of the land they cover is much smaller (Mountain Agenda, 2002). In Italy, mountain areas account for around 47.5% of the country, and are home to about 1/5 of the population (FAO, 2014, FMI (Fondazione Montagne Italia, 2016)). Italy is also emblematic of the enormous variety of climatic, morphological and socioeconomic conditions that the term "mountain" encompasses. The many mountain areas in Northern, Central and Southern Italy are very different from each other in terms of the problems they present and the resources they offer. Since the Second World War, the major part of Italy's mountain areas in both the Alps and the Apennines have known "perverse spirals" of underdevelopment marked by successive waves of demographic and economic contraction, dwindling services and decaying infrastructures. The exodus of manpower from the mountains to the industrial lowlands led to a decline in

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https://doi.org/10.1016/j.deveng.2020.100050
Received 15 February 2019; Received in revised form 6 November 2019; Accepted 23 January 2020
Available online 28 January 2020

population and the consequent abandonment of farming, forestry and grazing; this, in turn, reduced the utilized agricultural area (UAA). Between 1971 and 2011, Italy's total UAA shrank by more than one quarter, with the largest drop (−33%) taking place in mountain areas. Depopulation and the decline in agriculture were accompanied by a loss of public services and cuts in public spending on infrastructures and land maintenance. The hardships faced by residents in the course of their everyday life pushed more and more people to move away, further eroding the local system's response capacity.

The most recent studies (Cerea and Marcatoni et al., 2016; Marcantoni and Vetritto, 2018) emphasize that these problems were *not* inevitable and *some areas* have been able to avoid demographic shrinking. Between 1951 and 2011, two predominantly mountainous regions – Trentino-Alto Adige in the northeast and Valle D'Aosta in the northwest of the country– experienced an increase in their population by 41% and 36% respectively. Trentino-Alto Adige in particular has strong agricultural traditions and potential, but there can be no doubt that the region also has its share of natural constraints, as a significant portion of its surface is too steep or too high for intensive farming.[1] This would seem to show that, where agriculture has actively sought solutions, mountain areas may be able to flourish despite physical limitations (Sotte, Carbone and Corsi, 2005). In short, we can state that, by and large, mountain areas fall into two categories: mountains with serious problems of development differentials, and relatively wealthy mountains, with a range of urban and industrial municipalities, suburban municipalities (with above-average income), 'tourist' municipalities and small rural centers and innovative farming. The two categories are unevenly distributed, reflecting the well-known regional differences between northern and southern Italy as well as significant income disparities (Mantino, 2011). Notwithstanding these *internal differences*, mountain areas are defined as all those characterized by important limitations on land use or where difficulties in working the land make it impossible to increase the cultivable area (FAO, 2013). In fact, these aspects, which increase production costs and constraint productivity, add up to climate and weather conditions that shorten the growing season. Lastly, morphology must also be taken into account, as mountain areas often feature terracing or steep slopes that limit or rule out the use of machinery.

In almost all mountain environments, agriculture, forestry and grazing are key not just in connection to their economic impact, but also because of a series of positive environmental and socio-cultural externalities such as protection of the territory and the conservation of traditional and ecosystem heritage. Every mountain area, however, has its own way of farming and raising livestock, as the result of environmental and cultural factors. What these economic activities have in common is that they are largely "family-based" enterprises, where the family and the farm are closely linked, co-evolve and combine economic, environmental, social and cultural functions. This, as we will outline in the following, is often based on the integration of *multiple sources* of income, by the diversification of crops and a *combination* of forestry, husbandry and other activities that are not purely agricultural, such as catering and hospitality (multi-functionality). Often the multiplicity of income sources matches with "part-time farming" in which many the family members have a job outside farm. This kind of agriculture, which can also be called (neo)'peasant' farming (Van der Ploeg, 2009), is one of the predominant forms worldwide in developed and developing countries alike, employing around 2.6 billion people or 30% of the world's population. Around 99% of the people employed in agriculture are involved in small family farms (FAO, 2013).

[1] For the sake of precision, it should be said that only in Alto-Adige (South-Tyrol) agriculture *per se* has a central role; while in the Trentino area there is a stronger difference between farms with livestock and those focused on fruit growing and vineyard.

3. Low-land and mountain agriculture in Piedmont: similarities and differences

The mountain areas of Italy's Piedmont region (Fig. 1), which is the territorial focus of this paper, are part of the Alps-Mediterranean Euro-region and the Alpine Macro-region. Piedmont can be subdivided into three concentric bands. The outermost and largest is the Alpine and Apennine band, which accounts for 43% of the region's surface area. These mountains encircle the hilly area (31% of the region), which in turn surrounds the flatlands (26%).

It is well-known that mountain agriculture is strongly based on family-farming (Fao, 2014; Pierri and Hassan, 2015). But this label risks to be a statistical figure that – just like a mask – veils as much as it shows. This ambiguity directly derives from the very definition of "family--farming" or "family-agriculture" which, on the one-hand, is spelled out in connection with the predominantly domestic nature of work in the company and, on the other hand, is considered synonymous with "small-scale" and peasant agriculture. These dimensions may not be correlated and thus the category of "family-farming" needs to be disentangled and empirically assessed. For instance, while mountain agriculture is certainly small-scale, it can produces income from a variety of sources, connected both to multi-activity of family members and multi-functionality of firm activities in "quality-based" markets. Even in the small-scale agriculture of high-land family farming, moreover, farms living only with income coming from agriculture are very few.

To begin with, data certainly shows that mountain agriculture and family-farming are closely connected. According to the National Institute of Statistics (ISTAT , 2010), approximately 97% of the farms located in marginal areas of the Piedmont region are family-based. Of the over

Fig. 1. Orographic map of Piedmont.

66,000 farms of Piedmont that rely exclusively on family labour, 9450 are located in the mountains and almost 34,000 in the hills. These data show how important family farming is in Piedmont, especially in mountainous and hilly areas, which together host about 66% of this type of enterprise. In addition, most of these farms have fewer than 10 ha of utilized agricultural area (ISTAT , 2010). A small but far from negligible proportion of farms and farmers produce exclusively for self-consumption: in Italy as a whole, they account for about 11% of the farms surveyed. But, as we will illustrate in the following, farms living *only* with income coming from agriculture as such are very few.

To proceed in this direction we need to align our classification criteria with the legislation used to define the interventions and policies for mountain areas. To this end, the criterion introduced by Law 991/1952 classifies the municipalities of Piedmont as 41.7% totally mountainous and 2.2% partially mountainous (Table 1). This formal definition was adopted in order to assign economic incentives and subsidies to candidate rural districts through dedicated development strategies implemented at national and regional scales (Sallustio, 2018).

The first and perhaps most important point to consider when examining family farming in mountain areas concerns the reduced availability of useful agricultural area (Fig. 2). Material constraints (e.g. reduced space, steepness, small volumes) impose severe limitations of productivity. This is why, even if correct in principle, over-mechanization is not a proper solution for high-land peasant agriculture, which is not capital-intensive.

In this connection, it must be noted that arable land agriculture and livestock activity have a different distribution in low-land and high-land (Table 2). The percentage of farms in the mountains that practice livestock activity is almost triple compared to low-land, while arable land agriculture and permanent crops are higher in low-land. The only other specializations that slightly prevail in the mountains, compared to the low-land, are those that concern the poly-culture and mixed-practices. These data highlight an approach aimed at making the most of scarce and differentiated resources and reducing the economic risk accordingly. In mountains, the economic performance of the breeding of herbivores produces much less than in the lowlands. It must be said that these considerations are formulated in the current state of technology and skills, but if different kinds of technology exists – as we will argue – the economic performance of mountain farms could be different.

It is worth to point out that mountain farms, smaller, less productive and less equipped with technological and financial means, increase the push towards vertical integration of activities, production differentiation, multifunctional and multi-sectorial expansion of activities. This is why the label "family-farming" – which is for sure a statistical fact – needs to be better specified and elaborated. Presumably, these features are ways of trying to control market uncertainty and to increase margins, both upstream and downstream. This effort is entirely consistent with a "quality-based" economic strategy that links the value of the product to the *aura* of mountains in the eye of consumers. In this direction (Table 3) seems to go the strong slant of mountain farm towards organic farming and the efforts to expand the company's activities on the tourist and socio-cultural side, with educational farms, agritourists activities and other "relational" activities, which are more practiced in the mountains than in the low-land, *despite* the difficulties given by the travelling distances. Mountain farms develop even more on the socio-environmental side, where forestry and woodworking activities can constitute an economic integration of the main activity.

Table 1
Number of Piedmont municipalities in high-land and low-land.

Category	Total	%
Non mountainous	676	56,1
Partially mountainous	27	2,2
Totally mountainous	503	41,7
Total	1206	100

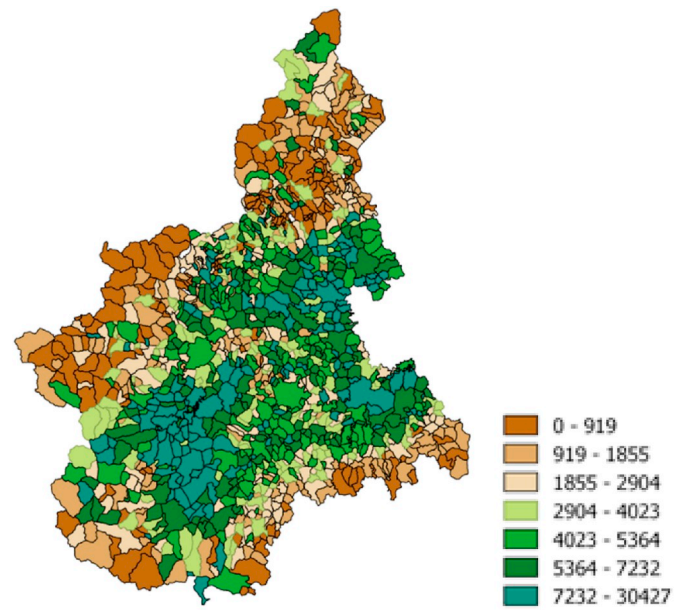

Fig. 2. Useable Piedmont Agricultural Area per square kilometer. Source ISTAT, Last available Agriculture Census 2010.

These features are coherent with the sale strategy of mountain farms vis-à-vis lowland ones (Table 4). Direct sales to consumers and sales to other farms are much more common in the mountain agriculture. Therefore, in a situation of relative territorial marginality, mountain farms survive and develop productive and commercial strategies that leverage on short-chain, horizontal cooperation and personalization of the product.

Finally, the connection farm-family re-emerge clearly when looking at the organization of labor force within the economic unity. As data show, mountain farms have a higher percentage of family members within the labour force compared to low-land (94,1% vs. 87,8%).

4. Appropriate technologies for high-land farming

Recently, Piedmont has been characterized by a resurgence of interest in heritage varieties of grains and other native crops such as hemp and buckwheat, which are better adapted to the area's climate, altitude and soil type. They thus require less irrigation and fewer pesticides, and are consequently also suitable for organic cultivation.

Piedmont is the region where the Slow Food movement was born, and also where the high-end food retailer Eataly opened its first store. It is a region where peasant agriculture in mountain and hill areas lives side by side with intensive agriculture in the flat land. Piedmont is, along with Tuscany, a key region for wine production and exports of quality food. It is also a region where small and organic vineyards flourish and co-exist with large-scale food production and distribution (Corsi et al., 2018). In such a setting, technology and machinery for "high-lands" agriculture should play a far from secondary role. However, though agricultural engineering has undeniably made great strides over the past 60 years, its main thrust has been almost exclusively towards developing larger, technically more complex (and very expensive) machinery, or towards maximizing productivity. This approach, substantially dictated by the dominance of industrial lowland agriculture, is rarely suitable for marginal farmland, where low production volumes, difficulties in accessing and manoeuvring in the fields and, not least, the limited funds available to small family businesses are the main obstacles to mechanization. In the absence of suitable machinery, the alternative is often manual work, with all that entails in terms of time and effort, or – as noted above – partially or completely abandoning the land.

The needs of small-scale mountain agriculture can be met through an

Table 2
Number of agricultural enterprises by technical-economic specialization and mountain areas.

Specialization	Classification							
	Non mountainous		Partially mountainous		Totally mountainous		Total	
	N.	%	N.	%	N.	%	N.	%
Arable Land	15.975	**34,7**	1.150	22,9	2.930	20,1	20.055	30,6
Vegetables- floriculture	1.231	2,7	138	2,7	219	1,5	1.588	2,4
Permanent crops	16.543	**36,0**	1.905	37,9	4.514	30,9	22.962	35,0
Herbivores	6.002	13,1	1.022	20,4	4.932	**33,8**	11.956	18,2
Granivores	767	1,7	77	1,5	103	,7	947	1,4
Poly-cultures	2.610	5,7	417	8,3	1.025	**7,0**	4.052	6,2
Poly-breeding	98	,2	13	,3	41	,3	152	,2
Mix – crops and breeding	2.339	5,1	281	5,6	821	**5,6**	3.441	5,2
Non classified	426	,9	18	,4	20	,1	464	,7
Total	45.991	100,0	5.021	100,0	14.605	100,0	65.617	100,0

Our elaboration on Istat data, agriculture Census, 2010.

Table 3
Associated activities of agricultural enterprises in Piedmont.

	Classification							
	Non mountainous		Partially mountainous		Totally mountainous		Total	
	N.	%	N.	%	N.	%.	N.	%
Organic production	711	1,5	260	5,2	1007	**6,9**	1978	3,0
Territorial denomination labels	1775	3,9	220	4,4	566	3,9	2561	3,9
Processing of vegetable products	355	,8	29	,6	147	1,0	531	,8
Processing of animal products	304	,7	30	,6	565	**3,9**	899	1,4
Wood processing	132	,3	20	,4	204	**1,4**	356	,5
Forestry	137	,3	21	,4	306	**2,1**	464	,7
Touristic farmhouse	667	1,5	46	,9	333	**2,3**	1046	1,6
Recreational and social activities	135	,3	12	,2	67	**,5**	214	,3
Educational farms	158	,3	19	,4	75	**,5**	252	,4
Handicraft	45	,1	2	,0	36	,2	83	,1
Total	45.991	100	5.021	100	14.605	100	65.617	100

Our elaboration on Istat data, agriculture Census, 2010.

Table 4
Sale channels of agricultural enterprises in Piedmont.

Sale channels	Non mountainous		Partially mountainous		Totally mountainous		Total	
Direct sales to the consumer in the company	6.803	14,8	656	13,1	3.345	22,9	10.804	16,5
Sale to industrial companies	7.045	**15,3**	333	6,6	1.069	7,3	8.447	12,9
Sale to other farms	9.296	20,2	1.342	26,7	3.562	**24,4**	14.200	21,6
Direct sales to out-of-business consumers	4.461	9,7	399	7,9	1.370	9,4	6.230	9,5
Sale or transfer to associative organizations	12.552	27,3	725	14,4	1.741	11,9	15.018	22,9
Sale to commercial companies	23.075	50,2	2.865	57,1	6.448	44,1	32.388	49,4

Our elaboration on Istat data, agriculture Census, 2010.

approach typical of the so-called '*appropriate technologies*' (Hazeltine B. 1999) or '*intermediate technologies*' (Schumacher, 1973), which aims at developing relatively simple, energy efficient small-scale tools using materials that are readily available in their intended setting. The appropriate technologies movement hinges on a distinct form of innovation referred to as retro-innovation: i.e., re-introducing elements and practices from the past into a new context, thus hybridizing traditional knowledge and new technological solutions. This means robust, low-cost machinery that requires little maintenance and can thus be properly managed by its target community. Agricultural machines can also encourage innovative approaches to farming techniques, making processes sustainable both environmentally and economically. They can also return land to cultivation, make farmers' work less tiring, and reduce the use of dangerous substances on crops. Many different actors must thus participate in their design: end users, machine manufacturers, university research centers and other local stakeholders (Fig. 3).

Designing appropriate technologies – namely "place-based" technologies for mountain areas and peasant-family-based micro-enterprises – forces us to rethink the notion of technological evolution. Technology should not be understood as a *replacement* of the old by the new, but as *recombination* of the old with the new. As Bruno Latour has noted (1993, 72–76): "modern time, where this behaved as moderns believed, has never existed. Time was always jumbled up, in the pre-modern era, the post-modern era and the modern era. We worked with old and new things, with hammers and electric drills. […] technologies do not only appear, they also disappear and reappear, and mix and match across the centuries" (Edgerton, 2007, xii). The *replacement* perspective holds that change occurs in stages between discrete entities, considered as "complete and coherent" wholes that follow and replace one another over time. A user-centered perspective would instead be to see technological evolution as being built not *on the ruins* of the past, but *with the ruins of it.*[2]

[2] The phraseology is adapted from Stark (1993), who applied it to the market transition of former socialist countries.

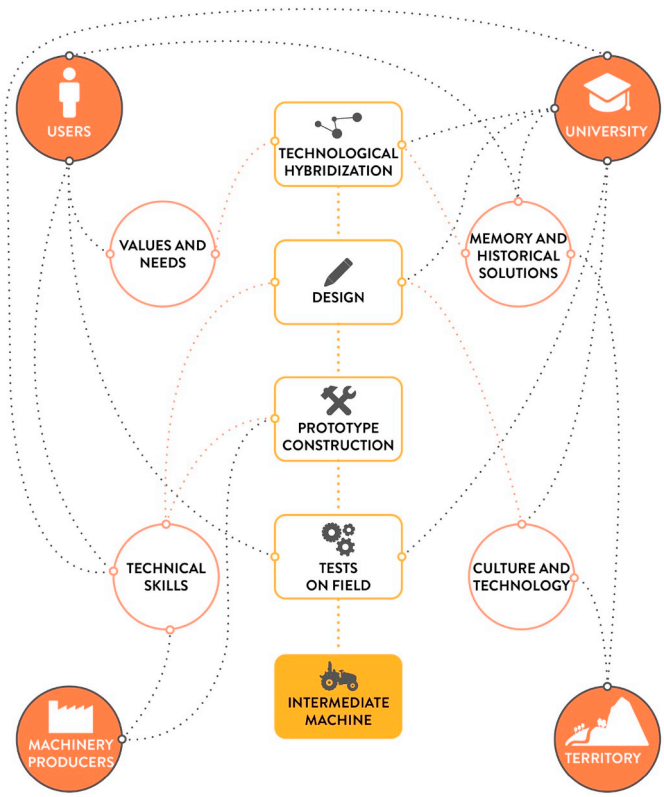

Fig. 3. Actors involved in co-designing agricultural machinery for small-scale mountain agriculture.

5. Research project and methodology

The aim of the research is the definition of a methodology for the development of devices and intermediate machines at the service of peasant mountain agriculture. The methodology involves two main phases (Fig. 4): the first consists in the study of the *scenario*, the second in the development of an appropriate approach to machine *design*.

In particular, first we dealt with a detailed exploration of the scenario, including the *target analysis*, the *identification of the needs*, and the *study of the state of the art*.

Subsequently, using the meta-design approach, which originated in the 1960s from the need to rationalize the stages of design with particular attention to different social, environmental, cultural, technological, ethical and biological values (Germak, 2008), we developed a specific method of design for appropriate technological solutions and agricultural machinery for mountain use. The *co-design* methodology provides for direct interchanges between users, local community and designers, while also drawing on input from machinery producers. The methodology also includes the *re-design* of effective ancient solutions, and moreover seeks to graft new technologies onto traditional solutions through a process of *technological hybridization*.

5.1. The scenario definition

To fully identify the requirements of small-scale mountain farming in terms of mechanization, the reference scenario was investigated through three distinct and parallel processes: the *target analysis*, the *needs identification* and the *state of art study* (Fig. 4).

As indicated in the introduction, the *target* is that of peasant family farming, which plays a significant role in Piedmont's mountain areas. Attention focuses on small farms in areas that are difficult to access, terraced or steeply sloping, where current mechanization is not very effective. Particular attention was devoted to the so-called "new mountaineers" who voluntarily choose to settle in a mountain area. Attracted by the mountain's natural beauty, the new inhabitants are in search of a balance between productivity, quality of work and quality of life, and often bring new values and new ways of working (Corrado et al., 2014; Pettenati, 2010; Membretti et al., 2017; Barbera, Dagnes and Membretti, 2018).

The *need identification* involved two distinct stages (Fig. 4): (i) the locally-based public focus groups; (ii) the face-to-face interviews.

The public focus groups were organized in several small towns in Piedmont that differed in geographical characteristics and crop types (Table 5). This made it possible to identify needs and problems, resulting in a fairly complete map of the multiple farming activities in the various mountain communities.

The focus groups also involved local authorities, municipal administrations, stakeholders, farmers and small business owners in open

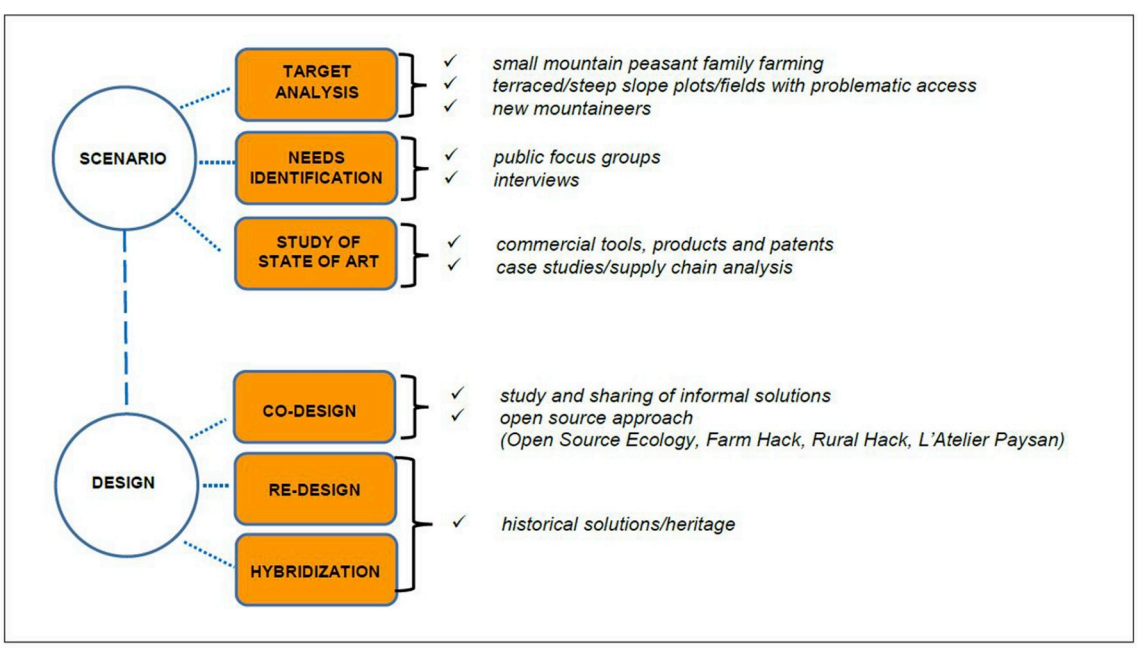

Fig. 4. Outline of the design methodology.

Table 5
Locally-based focus-group.

Place	Characteristics	Main crops	Participants	Duration
Pomaretto (TO)	Mid-altitude valley	Wine grapes and fruit	6	2 h
Momperone (AL)	Hills and plains	Wheat, grains, wine grapes and alfalfa	10	3 h 30 min
Dronero (CN)	Mountainous	Berries, strawberries, chestnuts, medicinal herbs and fruit	17	2 h
Mondovì (CN)	Mixed hills, plains and mountains	Chestnuts, small fruits, grain and wine grapes	12	3 h 30 min
San Giorio di Susa (TO)	Mountainous	Vegetables and chestnuts	15	2 h 30 min
Villar Pellice (TO)	Mountainous	Sheep, goats, cattle and chestnuts	15	2 h 30 min
Bossolasco (CN)	Mountainous	Hazelnuts and grain	25	2 h 30 min

discussions and exchanges of views on the topic. The needs analysis thus followed an approach based on the aggregation of internal diversity within the area, whose goal was to generate a collective voice and a "capability for voice" of voice-less actors (Barbera, Negri and Salento, 2018). As pointed out above, agricultural mechanization has been dictated by the needs and interests of large lowland agribusinesses. This has led to an overwhelming organizational dominance of the institutional and technological environment: the industries that produce technological inputs are in charge of "governance" decisions that were once made on the farm. As a result, farms have been forced to reorganize in ways more suitable for development models based on economies of scale, and the high sunk costs of this reorganization have in turn locked farmers in to technological paradigms that are unsuitable for mountain areas and the geographic and economic constraints they entail.

In addition to the focus groups, ten face-to-face interviews were carried out with key informants (farmers, small business owners) who dealt with issues of interest to them (Table 6). Like the focus groups, the interviews were conducted in a variety of settings, including farms, organic producers of cereals and legumes, bio-farms and dairies. The interviews highlighted a number of problems to deal with: economic constraints on purchasing suitable equipment and machinery; finding machinery specifically designed for hilly or mountainous areas on the Italian market; adapting small-scale solutions that are compatible with terraced land or steep slopes and, lastly, living in a social-political-cultural context that pays little attention to mountain agriculture and its needs.

Regarding the *state of art*, the products currently available on the market were analysed to meet some of the needs emerging from the background survey. The products were classified on the basis of their function: driving and driven machines for soil tillage, fertilizing, sowing, haying and forage harvesting and for cereal growing. The main features of each were reported, including installed power, productivity and cost (Table 7). However, it should be noted that the market response to the real needs of mountain family farming is not very adequate. Although there are multiple solutions, they are often very expensive, suitable for high volumes of production and capital-intensive agriculture, and not appropriate for steep sloped terrains. In addition, as it will be discussed in section six, there are specific needs of the contexts under study that do not present adequate commercial solutions. The state of art was also completed with an illustrative analysis of a number of cases and a detailed investigation of some agricultural supply chains, in particular hemp and wheat. Some of the cases dealt with small farms that have attempted to overcome the difficulties that mechanized farming involves under mountain conditions by using rotary tillers and animal traction. Others concerned cableways and monorails installed to facilitate grape handling in small vineyards; mini-threshers and mini-combine machines imported from Southeast Asia and intended for high-altitude cultivation of grain, cereals in general, legumes; small crawler tractor implement systems to increase work capacity and quality.

Table 6
Interviews with privileged witnesses.

Place	Duration
Sambuco (CN)	1 h 10 min
Boves (CN)	1 h
Confreria (CN)	45 min
San Damiano Macra (CN)	30 min
Alagna Valsesia (VC)	2 h
Monterosso Grana (CN)	1 h 45 min
Santo Stefano D'Aveto (GE)	1 h
Demonte (CN)	1 h 10 min
Pianezza (TO)	33 min
Caraglio (CN)	1 h 30 min

5.2. The design methodology

Once the needs are identified, the focus shift to the machine design phase (Fig. 4). Unlike what happens in the design of machines for lowland industrial agriculture, guided almost exclusively by the experts of R&D offices, we believe that the design process of equipment for peasant mountain farming, it must also involve the final users (farmers), as well as small and medium-sized enterprises, local authorities and research centers (Universities). It is therefore a shared design, called *co-design*, which provides equal collaboration between all participants, regardless of their professional qualifications or background. It thus fosters dialogue and exchanges of views between different actors that contribute to the design of a product, good or service. Thus, the co-design approach enables small-scale farmers and small business owners to contribute with their own personal experience to the development of projects that meet their specific needs and requirements, up to production (*co-production*).

To confirm the consistency of the contribution to the design of new machines by the farmers themselves, it should be pointed out that interviews and focus groups showed a marked ability of end users to independently find solutions to their own mechanization problems not addressed by available equipment. This it is strongly based on *co-design* and self-construction of informal solutions or on *re-design/hybridization* of historical solutions (Fig. 4).

Informal solutions show how the co-design and self-construction of specific machinery with low technological content can often facilitate farmers' work, especially in hilly and mountainous areas. Self-production can thus be considered a valid practice in the field of appropriate mechanization for marginal areas, since the end users themselves participate directly in the design, production and construction of their machinery. These self-designed and self-built solutions can also lead to valid design ideas for the development of products that are well adapted to the target's needs.

A good example is the case of a chestnut farmer from Villar Pellice (Torino), met during the research and analysis stage of the study. The man needed a machine for separating chestnuts from burrs, but was unable to find a model providing good performance at affordable cost on the market. He thus decided on a DIY (Do It Yourself) approach. His machine (Fig. 5) is driven by a tractor power take-off and consists of a rotary shaft to which several hammers are hinged. The hammers rotate, forcing the full chestnut burrs to pass through bars spaced at a suitable distance, thus separating the burrs from the chestnuts. As the chestnuts are smaller and denser than the empty burrs, they fall through a metal grid and accumulate on the ground. The empty burrs remain on top of the grid, and are blown off to the side by fans.

Another example of informal innovation concerns the development

Table 7
Summary of the state of the art.

STATE OF ART SUMMARY			
Type of machinery	Country of origin	Price range - €	Strengths and weaknesses
Two-wheel tractors	ITALY, SWITZERLAND	1400–14,200	Excellent versatility, manoeuvrability and grip. Can mount a wide range of attachments and operate on steep slopes. Wide range of prices.
Isodiametric tractors	ITALY	25,550	Low center of gravity and tight turning circle. Poor stability in sloping curves. High cost
Dumpers	ITALY	3700–5500	Light weight, high load capacity and traction, excellent steering and manoeuvrability in tight spaces and on slopes. Interchangeable accessories.
Monorails	ITALY	/	Transport system capable of running without direct operator intervention, thus lowering costs and saving time. Can be used for adjoining fields.
Radio-controlled tractors	ITALY, SWITZERLAND	30,000–43,000	Multifunctionality, prolonged use over slopes up to 50° in any direction. High cost.
Forecarts	GERMANY, ITALY	1800–2500	Multiple attachments provide versatility.
Rotary harrows	SWITZERLAND	/	Manoeuvrability in tight spaces.
Cutters	ITALY	/	Operates in all slope conditions.
Weeders	CHINA, ITALY	580–2745	Small, practical and competitively priced machine. Lightweight and manoeuvrable. Wide range of prices.
Tillers	JAPAN	1084	Compact size, low center of gravity.
Multipurpose tools	ITALY, FRANCE	337–3800	Adaptable for medium-small fields.
Seeders	CHINA, NIGERIA, LUXEMBOURG, ITALY	25–760	Can work on several rows at the same time. Adjustable sowing distance and furrow depth.
Backpack fertilizer applicator	SOUTH AFRICA	53	Versatile low cost machine suitable for all types of terrain.
Mowing bars	SWITZERLAND, ITALY	2400	Low power consumption, light weight.
Mowers	ITALY, GERMANY	2100–21,500	Rotary mowers attached to compact tractors, radio-controlled in some cases. Prices can be high.
Grass shredder	ITALY, FINLAND	210–6900	Can be used on sloping, uneven and uncultivated terrain. Excellent stability and operator safety. Wide price range.
Brush cutter	ITALY, JAPAN, GERMANY	348–2120	Can be used on sloping and uneven terrain. Wide price range.
Forestry mulcher	ITALY	/	Suitable for forestry operations.
Log lifter/ loader	ITALY, GERMANY	68–1005	Small size, useable with small and medium power tractors or manually. Easy access to logging area. Wide price range.
Sprayers	ITALY	698	Compact, readily adaptable machines.
Flower picking machines	ENGLAND, CANADA	1880	Can be used on rough terrain, and in delicate area and nurseries.
Reaper-binder	CHINA	1700	Compact unit capable of cutting two or more crop rows. Suitable for different crops in small plots, hills, mountains and hard to reach areas. Wide range of prices.
Combine harvesters and threshers	CHINA, ITALY, AUSTRIA	510–24,000	Compact and versatile machines for different types of crops. Main problems include machine durability and the quality of the materials used in construction. Wide range of prices.
Cereal cleaners	ITALY	3780	Adaptable to different cereals and seeds. Low power consumption.
Grain hullers	ITALY	3900–7200	Good performance in hulling and winnowing operations.
Mills	ITALY, CHINA, AUSTRIA	219–359	Different versions available to meet the needs of small or larger scale milling.
Plows	ITALY	/	Adaptable to different terrains and hard or compact soil. Adjustable plow depth. Versatility over a range of slope conditions,
Manure spreaders	ITALY	/	Can be used in narrow rows thanks to its small size.
Mechanical presses	ITALY	/	Double extraction heads.
Milking wagons	ITALY	2500–11,500	Tailored solutions for any type of work environment.

of a machine for detaching dry leaves from the stem of the oregano plant. In this case the farmer from Pantelleria (Trapani), known during a similar study we are conducting on the island, reused recycled material to make the machine. An old treadmill moves the oregano plants, which are retained by an overlying structure, made with the wire mesh of an old bed. In the dragging motion the plants are rolled, the dried leaves detached and transported in a collecting bag (Fig. 6).

Since this type of innovation generally does not spread beyond the area where it was invented, it is interesting to map the informal solutions adopted in a certain area and share them on specific platforms using an open-source approach. The central idea of the open-source approach is to provide goods and services while enabling the end user to participate. Open Source Ecology (2018), for example, is a network of engineers, farmers and activists from all over the world who actively collaborate to design and build construction sets, or plans, for agricultural and industrial machines, which are modular, recyclable, repairable and available online. The open source approach is an excellent match

Fig. 5. Self-produced chestnut deburring machine.

Fig. 6. Machine for detaching the dried leaves of the oregano plant.

with the simple construction of these machines (today, a total of fifty construction sets), which any type of user can replicate and build. The power of this philosophy for the world of agricultural mechanization consists in the fact that machines can be built for much less than the cost of commercial units, as the only outlays involved are those for purchasing materials. Similar examples of open source platforms include Farm Hack, Rural Hack and L'Atelier Paysan. On Farm Farm Hack (2018), each plan is accompanied by explanatory videos on machine operation and documents that can be downloaded free of charge, with details of all the components of the finished product and assembly instructions. The second platform, Rural Rural Hack, (2018), seeks to provide farmers and others in the sector with the skills and knowledge needed to create products and infrastructures, and thus become independent and self-determined makers by acquiring skills and new abilities. Rural Hack focuses on greater access to cutting-edge technologies for low-cost precision agriculture. L'Atelier Paysan (2018) is a cooperative of farmers, workers and organizations that takes an innovative approach to agricultural development to enable organic farmers to reclaim agricultural skills. For the sake of clarity, we must specify that the networks above cited are not directly linked to this project, but we are starting a collaboration with Farm Hack.

Another widespread practice is the use of historical solutions (Fig. 4), eventually adapted in the design process. In fact, the experience gained in hundreds of years of mountain farming has shaped the tools and small manually-operated machines that stood agriculture in good stead until the post-war period. As mountain farms were abandoned, particularly in the 1960s and '80s, the ability to replicate and use these tools and machines was also lost, along with many practices and techniques. Where this cultural heritage has been preserved, the methods of the rural tradition are sometimes still effective. The recovery of historical technical knowledge, both through interviews and functional studies of museum material, can thus contribute significantly to innovation in mountain farming machinery and equipment.

Consider, for example, the use of a stationary manual thresher for small quantities of wheat in subsistence farming or for heritage varieties grown on trial plots (Fig. 7). By studying the traditional machine's architecture and functioning, it is possible to make an innovative

Fig. 7. Manual Thresher, Heinrich Lanz AG of Mannheim (early XX century).

contribution by engaging new technologies, using new materials and adding new solutions. Thus, as will be described in greater detail in the case studies section, the manually-operated static threshing machine's transmission efficiency can be improved by using a chain drive instead of gears, for example, or by adding a motor to assist manual actuation; likewise, measures can be taken to optimize the mechanical mechanisms, improve safety requirements, etc. Innovation – in its many shades and variations – can be generated not only by developing a product from scratch, without drawing on the market or the historical-cultural background, but also by studying existing solutions.

If the design of the new machine consist of simply revisiting an old device to create a new version that draws on the original, but updates it and improves its functional and technological performance we talk about *re-design* (Fig. 4). With this practice, we can start from traditional machinery and design a machine that is much more consciously adapted to today's needs, as in the case of manual threshing machines.

If the design consists of introducing new knowledge – techniques, materials and processes in low-tech elements arising out of tradition we refer to *technological hybridization* or *retro-innovation* (Fig. 4). For example, in the case of round bale loader for hilly ground of EQUI idea (Fig. 8) a modern hydraulic transmission technology is inserted in a traditional animal drawn cart. When the wagon stands still, a hydraulic accumulator allows to lower the bale fork, lift the bale, place it on the platform and move it to the rear in order to make space for the second bale. The accumulator is completely recharged when the cart moves about 20 m forward, the normal distance between one bale and the next.

6. The demand side of appropriate technologies

Our exploration of the historical-social-cultural scenario using the methodology described above enabled us to outline the target community's problems. The focus groups and interviews with key witnesses were one of the most important parts of this process, as they highlighted the multiple needs and experiences of individual participants. The recordings of the focus groups and of the interviews were again listened with the intention of re-examining them horizontally, and grouping the themes into homogeneous families. In the following description, the needs emerging from the research are clustered in macro-themes identified, indicating the characteristics, specifications, and functional and performance requirements for each and, in some cases, the experiences that proved useful in outlining the demand framework.

One of the issues that attracted most interest was the need for *shared equipment*. Sharing machinery was viewed as an effective way of coping with high equipment costs and the lack of funds affecting much of the target community. Apart from the obvious advantages of lowering costs, however, sharing involves numerous problems. For instance, the procedures for transferring equipment on loan to a given individual and ensuring that the machinery is safely used and maintained involve administrative and legal difficulties. It is thus necessary to devise sharing procedures that lighten the bureaucratic burden.

Another topic discussed was the need to limit *wildlife damage*: roe deer and wild boar are, in fact, the major cause of crop damage. The most widely expressed need is for a suitable technology to prevent crop invasion by these animals as an alternative to existing and not very effective methods such as sound deterrents, ultrasounds, wire mesh and chemical repellents.

One of the macro-themes that attracted most attention was *multi-functionality and adaptability,* i.e., the need for versatile machinery that can be used with different crops and situations. For example, there is a need for machinery that does not mix different grains, machines that can work on several rows at the same time, equipment with adjustable working widths and drive machines that can be configured with different implements and tools.

In addition, several discussions dealt with the physical conditions of mountain farming, where fields are often adjacent to *uncultivated land* and wooded areas. In particular, given the low financial return on reclaiming and maintaining these uncultivated areas for farming, there is a need to put them to use as timberlands or orchards, for example, thus obtaining a return from these otherwise unproductive areas.

Additional needs that were discussed include *remote-controlled methods* for cutting and eradicating spontaneous vegetation and for weeding abandoned cropland. Here, the market offers suitable solutions such as compact mulchers and shredders, brush cutters that can adapt to different slopes and remote-controlled solutions with excellent performance, but prices are high. Hence the need to consider what the market already offers, its potential, and the constraints for the reference project.

The discussions also mentioned the need to consider the entire *supply chain* when developing appropriate machinery. The topics that came up most frequently included: the need to recover the mills scattered throughout the area (Franco et al., 2019) to start small production operations; machines for threshing, winnowing and hulling cereals; the spread of small dairies along the valleys; machinery for processing small quantities of hemp, and chestnut deburring equipment.

Considering mountain farming areas' *terraced landscapes* and *very steep slopes*, the need also emerged for compact combine harvesters for small quantities of cereals and legumes that can perform well under these conditions. Such versatile low-cost machines are quite common in Asian markets. However, not only are there bureaucratic problems in importing these machines, but they also involve a number of critical issues, including the poor quality of the materials and components and a rather limited durability compared to an average useful life cycle. Moreover, these machines' productivity is often excessive for small farms. Lastly, there is the problem of access to land with rough roads.

A specific theme is that of *saffron growing*, which, though quite profitable, is still mainly carried out manually. Consequently, there is a need for small-scale mechanization to facilitate the harvesting process. In this regard, existing solutions were identified and tests were carried out on a portable shoulder-carried harvester prototype capable of

Fig. 8. Hydraulic round bale loader (Courtesy of EQUI idea).

detaching the flower without damaging the leaves. In this case, tests helped gain an understanding of the real needs and requirements of a non-mechanized operation.

Another macro-theme relates to *accessibility and manoeuvring problems*: plots in mountain areas are often very far from the main roads, with narrow entrances. In addition, there is the risk of machinery slipping on steep slopes. Given the complexity of the topic, many different needs were identified: e.g., drones for pest control and disease prevention; vineyard weeding machinery suitable for terraced land; and machines that can keep to a straight path when working across side slopes. The case studies examined for this macro-theme show that workers and machinery are well adapted to terrain conditions: in fact, it is common to use a brush cutter for weeding and maintaining the turf rather than consolidating the soil with particular tree species. Other more isolated cases made use of a radio-controlled crawler tractor prototype and a modified mono-wheel tractor that can negotiate side slopes without being damaged by subsurface stones.

As regards *vineyards*, focus group participants repeatedly emphasized the problems of excessive fragmentation, which makes mechanization difficult. Steep slopes are a further problem, as they are an obstacle in weeding operations. Mention was made of the use of crawler equipment, rotary tillers, and highly functional mini dumpers, though the latter are difficult to transport. Examples of particular cases included the adoption of a rack-type monorail to facilitate grape handling.

Other specific topics that were emphasized included the cultivation of *medicinal herbs*, where efficient mechanization is lacking, the *livestock sector*, where there are problems in transporting animals, as well as a need for mobile milking systems, the *cultivation of small fruits*, where it is necessary to replace manual harvesting with mechanized methods that facilitate and speed up the operation, the *haymaking* process, where the main requirement is for compact, light-weight equipment, and *self-levelling technologies* suitable for use on steep terrain.

Different opinions were voiced regarding *undergrowth management*, mainly in orchards and chestnut groves, where there is currently little attention to environmental sustainability (bonfires are frequently used to eliminate undergrowth, leaves and chestnut burrs, impoverishing the land and posing a wildfire risk). In this connection, the most widely expressed need is to eliminate brushwood while leaving organic substances that are beneficial to the soil on site: here again, possible solutions include robot and suction machines towed by or applied to small tractors/minidumpers. In addition, the question of *grassland farming* was raised, in particular the production indigenous grass seeds to maintain biodiversity and provide a source of income for the farmers. Identified needs included a seed picking and sorting machine, machinery to facilitate harvesting – likely carried out with a cutting and suction technique – and greater use of the hydro seeding technique, which has proven effective for maintaining ski slopes, controlling erosion and containing the spread of weeds.

In addition to these frequently expressed needs, some participants had more individual requirements, such as: reducing water use in vegetable growing; the need to enhance and protect marginal areas; the need for a machine for harvesting and trimming fennel; a screw-type horizontal log splitter; a small tractor-mounted manure spreader suitable for slopes and incorporating a manure packaging machined and, lastly, sowing machines and ridging machines for sloping terrain.

7. Some examples of appropriate machine concepts, design and prototypes

In order to validate our methodology, two design processes, conducted by the authors themselves, are presented. In our opinion, the examples demonstrate that, starting from an in-depth knowledge of the scenario, selecting a need in terms of partially unsolved mechanization, using an appropriate approach to the development of a new technology and involving users in the design process, eventually having memory of historical solutions, can be produced innovation also in the consolidated sector of agriculture machinery. Depending on the case, concepts, projects, laboratory prototypes or field-tested prototypes are presented. Only in the last case, obviously, it is possible to evaluate the concrete effects on the reference community.

7.1. Grain supply chain in terraced fields or steep terrains

One of the needs that emerged both in the focus groups and in interviews of experienced farmers (in almost all cases) was the development of small machines and devices able to perform some processing in the supply chain of the grain cultivated in fields with difficult access, for example terraced or steeply sloping terrains. In particular, many farmers have expressed the need for machines for reaping, threshing and cleaning small quantities of grain, especially in cases where a commercial combine cannot operate.

Until the end of the 1950s, in the Alpine valleys, the cultivation of cereals, in particular rye, was common both for human and animal nutrition, as well as for the use of straw as mulching material and in the construction of roofs. Often, given the high slope of the terrains, cereals were grown on terraced plots (Fig. 9), that they could not be reached except on foot or by animals. The harvest was done mainly manually, with the use of sickles or scythes, while the threshing, in the case of small family productions, was done using the flail, or by animal trampling in the farmyard. Cleaning of the grain was also done manually, using sieves during windy days. The wheat supply chain ended with the production of flour, through stone mills. The multitude of watermills present along the streams of the Alpine valleys testifies to the spread of cereal cultivation even at high altitudes (Franco 2019a, 2019b).

In recent years, there has been a renewed interest in the production of cereals for family use, even in the high mountains. Particular attention is paid to revaluate ancient varieties of cultivars, appreciated for organoleptic and nutritional properties. Reintroducing heritage cereal varieties in mountain areas is justified both in the case of peasant family farming, where production is mainly for self-consumption, and for high quality production aimed at short and local food supply chains for bread and leavened products. In the Sangone valley (Torino), for example, the "Ingraniamo" association is working to recreate the local wheat supply chain, with projects ranging from the recovery of heritage cultivars to the production of baked goods. Reintroduction is often a matter of high quality but limited quantity, as heritage cereals can also be cultivated in steep, terraced, unstable terrain served by rough roads or even mule tracks.

While numerous water mills capable of producing high quality whole-wheat flour have been recovered (Franco, 2019a), both the cutting, harvesting, threshing and cleaning operations, are extremely difficult. In fact the commercial solutions present on the market of combine harvesters or cleaning or threshing machines are not suitable in these contexts: (i) these machines cannot be used in fields connected by mule track; (ii) they have excessive productivity, which leads to high costs; (iii) in the case of solutions from eastern markets, they present safety issues and are not certified.

Fig. 9. Terraced land in Maira Valley (Cuneo).

A number of design parameters were identified through a benchmarking analysis, a survey of the state of the art, and interviews. They included the ability to process small quantities of cereals at rates up to 50 m^2/h for harvesting and 200 kg/h for threshing/cleaning, and the ability to work in hard-to-access sloping terrains. Other requirements included low consumption, affordability, ergonomics, stability, light weight, small size and easy maintainability.

A first solution has been proposed to solve the problem of cereal harvesting. It is a concept of an original backpack combine-harvester, viz., a compact unit that can be carried by single person, and is capable of cutting and threshing small quantities of wheat (Fig. 10). The device consists of a cutting and suction apparatus made up of rotating blades and a turbine (Fig. 11). This system is held by the operator, who directs it towards the culms of the ears. Once the ears of wheat are cut and threshed by the suction turbine, the grains are conveyed through a flexible corrugated tube to the separation and collection apparatus carried on the operator's back (Felizia, 2016).

Starting from the same scenario, a second solution has been developed focusing on the issue of threshing and cleaning. Missing an appropriate solution, many farmers still use old manually operated threshing machines (Fig. 7) and ancient cleaning machines (Fig. 12), properly restored and put into service. These solutions, while partially solving the problem, present some important critical issues: (i) they require excessive efforts for their functioning; (ii) threshing and cleaning are performed in sequence; (iii) do not meet safety requirements. Starting from the functional study of these ancient solutions, both on the machines still in use and on historical documents, a new threshing/cleaning machine, called Re-Thresher, was designed with the aim of satisfy the following requirements provided by the farmers: (i) threshing and cleaning in a single process; (ii) productivity of 100–200 kg/h of grain; (iii) compactness (1060 × 640 × 1245 mm) and lightness (120 kg); (iv) possibility of being transported in the field even on small mule tracks, so as to avoid the transfer of the straw; (v) possibility of working in the field even in the absence of grid electricity; (vi) low consumption of renewable energy; (vii) low cost; (vii) ergonomics; (ix) security. Fig. 13 shows the overall detailed project resulting from this analysis. The machine, is operated manually by means of two cranks, which transmit the motion to all the mechanical devices through chain drive transmissions. Thanks to high efficiency of the chain drive transmission, about 99% as known in the cycling field (Wilson, 2004), it was possible to operate manually and simultaneously both the threshing and the cleaning sections with an acceptable input power (re-design of old solutions). Moreover, the assistance of an electric bicycle motor powered by a lithium battery with 12 h of autonomy, was included, so that the machine can be used without fuel and grid electricity (technological hybridization). The operator, holding the grain sheaves, introduces the grain ears into the feeding mouth of the machine (Fig. 13 opening on the left). The ears are threshed between the teeth of the rotating threshing cylinder and the fixed casing. The detached grain is conveyed, by falling along an inclined wooden plane, onto a series of oscillating sieves, moved by a mechanism actuated by the chain drive transmission. The chaff and straw are then separated from grain by the joint action of two oscillating sieves and the air flow generated by a centrifugal fan. Straw and chaff are discharged to the outside of the machine (Fig. 13, opening on the right), while, after the removal of impurities of reduced dimensions with a fine-meshed grid, the grain is collected in a drawer placed under the sieves. A prototype of the Re-Thresher has been realized and tested in laboratory, demonstrating its functionality (Fig. 14).

Fig. 10. Backpack combine harvester concept.

Fig. 11. Backpack combine harvester functioning.

Fig. 12. Traditional cleaner (winnowing) of Piedmont (Italy).

7.2. Human powered baler

The design methodology was tested also in a different context from the Piedmont mountain one, to verify its resilience. In particular, it was implemented in an international cooperation project followed by Architettura senza Frontiere Piemonte association (Architecture Without Borders Piedmont) aimed at identifying the needs of farmers in the area of the Artebonite Valley (Haiti). In this case, the interviews revealed, among the others, the need to re-use rice straw, currently treated as a by-product of cultivation and burned in the fields. In the absence of motorized balers, the idea was to create a human powered baler for the production of straw bales to be used as a building material, instead of raw earth blocks (Ferraresi et al. 2011, 2017a; Sassu et al., 2018). Straw bale buildings in fact can improve housing conditions in poor countries (Ferraresi et al., 2017b). Straw is a sustainable, low-cost, renewable, and readily available construction material. It is also very suitable for buildings thanks to its insulating, anti-seismic properties and fire resistance when plastered. Straw is also a suitable material for

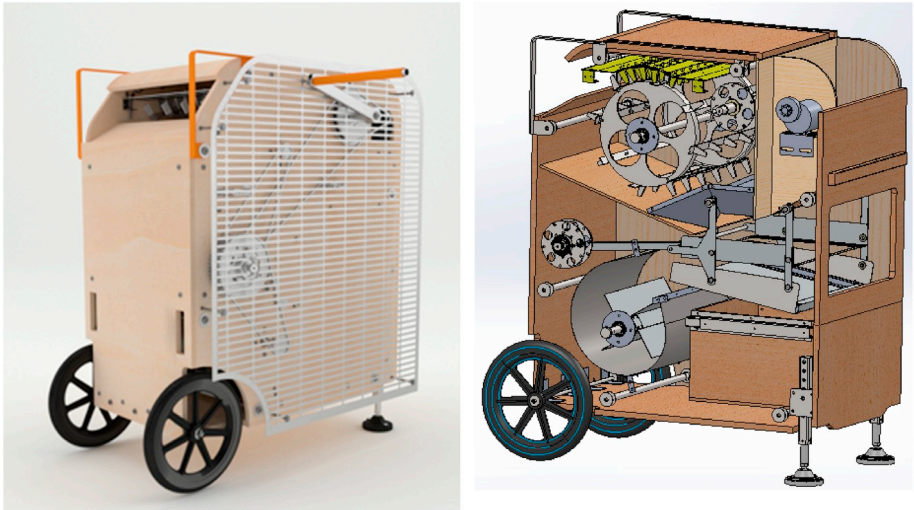

Fig. 13. Static thresher-cleaner machine concept (Re-Thresher).

Fig. 14. Laboratory test of the prototype of the Re-Thresher.

Fig. 15. Manual baler Anpilpay 2.0.

self-construction, especially in rural areas. Our design focused then on a press capable of producing straw bales of high and adjustable density. The operating lever actuate a slider-crank mechanism that compress the straw (Anastasio et al., 2017; Ferraresi et al., 2018; Franco et al 2016, 2017). Considering that one of the aims of appropriate technology is to involve communities and encourage a sustainable self-construction process at the local level, the machine is simple, ergonomic and easy to implement using locally available tools (circular metal saw, angle grinder, welding machine, drill). In fact the press was realized in different prototypes in Haiti (Fig. 15), used to produce straw bales employed in the construction of a warehouse and several houses, with evident improvement of the quality of the live of people. As a further demonstration of the validity of the technology, the same press is currently replicated autonomously in different areas of India.

8. Conclusions

The opportunity-window for developing machines for mountain farming with an approach based on retro-innovation, re-design and technological hybridization is, as illustrated above, considerable. This approach is key for the development of simple, low-cost machines that require little regular maintenance and are fully compatible with existing machines – respecting the principles of adaptability and multi-functionality. This "user-centered" perspective calls for design processes where different orders of worth and quality conventions confront each other (Stark, 2009; Boltanski and Thévenot, 2006). This requires "discovering" the innovators giving space to the marginal family farming and mountain farming in the "evolution" of technology. To be able to escape from under-development traps and make innovations, the *practical knowledge* embodied in the places and people who live there need to be brought out and combined with *technical knowledge*. Appropriate technologies thus require a "user-centered" and systemic approach, where different modules of practical and technical knowledge *hybridize* to solve a practical problem for the user. For these reasons, "solution-oriented" approaches require research to reject the traditional distinction between basic and applied science, and instead seek to advance theory specifically in the service of solving real-world problems (Watts, 2017). Research in support of intermediate technologies also requires relinquishing "prestige" and excellence-based projects in favour of *bread and butter* research and development. Technological hybridization, redesign of informal solutions and open-source approach, moreover, are not enough to catalyse innovation in mountain farming. In this connection, rural regions' decision-making processes and limited

ability to influence the market and public policies also put them at a disadvantage. This is not only due to endogenous constraints, but also to a public discourse that does not encourage the innovative potential of small-scale mountain farming. The equation stating that "local development = smart city + creative class + hi-tech solutions", in other words, overshadows the innovation potential of marginal areas.

This standpoint bears several consequences for the so-called "co-design for development" approach. Most of times the problem of appropriate technologies is framed as merely descriptive and/or "applied", while we have been suggesting that it has a key theoretical backbone. In this vein, as Oosterlaken (2009) aptly underlined, a distinctive trait of technological artefacts is that they are resources whose properties can be "shaped" to support human capabilities and well-being. Capabilities point to the effective opportunities that people have to "live the lives that they have reason to value", in Amartya Sen well-know definition. In other words, technological artefacts are strongly intertwined with human capabilities that allow goods and services to be translated into functioning (Sen, 1999). In this respect, we should always keep in mind that technology is and has always been a tool to increase our capabilities as human beings. Technologies *per se* are inert tools that need to be "converted" into well-being: a last generation smart-phone does not help a deaf person to hear better, as much as a last-generation farm tractor does not help a small-scale farmland working in mountainous areas. To build effective capabilities, conversion factors need to be taken into account. Conversion factors can be individual, social, territorial and environmental and they all matter for the "co-design for development" approach. In this vein, engineering and design need to be understood – as Science and Technologies Studies have been painstakingly illustrating – as increasingly intertwined with society, institutions, laws, and procedures. In STS the social dimension is declined rarely, if ever, through territorial categories using a *place-based* approach. But – as we argued – just in this way technologies can within certain limits be designed in such a way that they take key local conversion factors into account. The "co-design for development" approach, in other words, recognizes the social imprinting of technologies as in STS and, through Sen's capability perspective, it point to those *place-based* conversion factors able to translate technological solutions into well-being of users.

In this connection, we have been arguing that the "social" features of technology and design should be considered as place-based tools, useful to calibrate territorially the most effective design solutions. And this is far from being a "technical" posture, since it involves several and intertwined dimensions: "Take a bicycle.… Having a bike gives a person the ability to move about in a certain way that he may not be able to do without the bike. So the transportation *characteristic* of the bike gives the person the *capability* of moving in a certain way. That capability may give the person utility or happiness if he seeks such movement or finds it pleasurable. So there is, as it were, a *sequence* from a commodity (in this case, a bike), to characteristics (in this case, transportation), to capability to function (in this case, the ability to move), to utility (in this case, pleasure from moving). The details of design are morally significant" Oosterlaken (2009).

This approach to technology, which we have applied to the case of mountain agriculture, drives the attention to the need to adapt technological solutions to "diversity" in a broad sense. As Suggested by Frediani (2007), participatory methods are one way of identifying, exploring and evaluating the dimensions of well-being in connection to agency, voice and choice of marginal actors and places. In agriculture, the modernization process has whittled away at the importance of the assets held by the individual farmer or the local community, such as land, labour and local knowledge. By contrast, the assets, both tangible and intangible, on which agents other than the farmer exercise property rights have gained importance. This category includes agricultural machinery, seeds, chemicals, administrative and market services. All this has led to a real organizational dominance of the institutional and technological environment, and governance decisions have passed from the farm to the industries that produce technological inputs. Consequently, farms have had to reorganize in ways more suitable for development models based on economies of scale. At best, these models serve the needs of lowland agribusiness: marginal voices of mountain farmers did not find space in this process. Mountain areas are certainly not able to influence public policies, as they are demographically weak and do not serve the mechanisms of political consensus for the ruling class. Moreover, organizations of interests defend the "needs" of lowland farmers and the development of technological paradigms that are unsuitable for the productive structure of family farming in the mountains. Appropriate technologies – if regarded from a place-based standpoint – are also key entry points to the problem of inclusive governance for these areas.

Author contributions

The article is the result of a collective work. Nevertheless the specific contributions of the single authors can be subdivided as follows. Introduction: Barbera; The role of mountain agriculture worldwide and in Italy: Barbera; Low-land and mountain agriculture in Piedmont: similarities and differences: Barbera; Appropriate technologies for high-land farming: Franco; Research project and methodology: Franco; The demand side of appropriate technologies: Bartolucci, Focanti and Franco; Some examples of appropriate machine concepts, design and prototypes: Bartolucci, Felizia, Focanti and Franco; Conclusions: Barbera.

Acknowledgments

Our gratitude goes in particular to the Accademia delle Alte Terre for its promotion of inquiry into the issues discussed in this paper, and to the Collegio Carlo Alberto for funding the research project.

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