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The Adoption of Good Practices for Pesticides and Veterinary Drugs Use among Peasant Family Farmers of Chile

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Abstract: Improvements and good practices (GPs) in rural environments are often developed by peasants themselves and shared among trust-based networks. The level of adoption of GPs by peasant family farmers (PFF) has been poorly studied. This paper describes the performance and results of the innovation adoption index (InAI) and rate (InAR) which were used to estimate the adoption of GPs for pesticide and veterinary drug use by PFF from eight different regions of Chile. Surveys were conducted among 257 farmers to find out about the adoption (yes/no) of a set of GPs in the adequate handling, use and storage of these chemical products, as well as some identifying information. The farmers in this study are producers of berries, dairy cows, honey and vegetables. The results of the survey showed an average of 57.33% GPs were adopted by farmers. Group averages of 55.23–61.32% were observed in the numbers of practices adopted by farmers. This survey data collection was part of a wider study intended to design a national plan to reduce chemical residues in food produced by PFF in Chile, with a focus on organizing practical workshops with extension officers and farmers.

Keywords: peasant family farmers; good practices; pesticides; veterinary drugs; innovation adoption index; innovation adoption rate; chemical residues in food

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1. Introduction

Satisfying the world's need for food with a growing population is a huge challenge for agriculture, which must meet not only the demand for healthy and natural products, but also the adaptation to, and mitigation of, climate change goals and the provision of fiber and a wide range of ecosystem services [1]. The use of pesticides and veterinary drugs is a common practice in food production, and includes correct and adequate use but also overuse and misuse. These bring the associated risks of having drug and pesticide residues over the maximum residue levels (MRLs) in the tissues of animals and plants treated, and so in products for human consumption [2].

Adequate risk management is critical to ensure good practices (GPs) in the use of veterinary drugs and pesticides [3]. The searches for alternative treatments and integrated pest and disease management practices also play an important role in delivering safe and quality food to the public.

Improvements in rural environments are often developed by peasants themselves and shared among their trust-based networks. Agricultural innovation—including the adoption of GPs—is an organizational process influenced by individual behaviors, interactions, and coordination, as well as collective actions based on the capacity of farmers to identify opportunities, evaluate challenges, access information, exchange knowledge, and access human, social, financial and natural resources [4].

The adoption of GPs in rural environments has been poorly studied in Chile. Moreover, there is no data on the adoption or knowledge of GPs by farmers when dealing with veterinary drugs and pesticides, even though compliance with GPs is essential to reduce the threats posed by the use of these substances in food production.

Rethinking rural extension requires important strategy changes, going from linear and hierarchical transference of technologies, to horizontal, interactive and participatory ones that promote farmers relationships and the territorial characteristics of projects. The idea is to shift from transference of predefined technologies, to innovation based on non-pre-established co-construction that occurs in the interactions between social actors in agricultural environments with different experiences, types of knowledge, and capabilities [5].

Innovation indices, such as the ones developed in this study, help to identify the actors in a network who have best solved the challenges posed by the environment, in order to design strategies and build bridges that facilitate interaction, with the purpose of triggering a collective learning dynamic [5], or "community of practice", at the end of the initiative. This implies that the actors, who play a leading role, can contribute their knowledge, creativity, and ability to experiment, learn and teach. Thus, there is a need to act as facilitators and not as instructors, since knowledge and innovation, instead of being transferred, must be created by the same actors through the systematic management and adaptation of available data and information [6].

This work analyzes a specific innovation, the adoption of good practices in the use of pesticides and veterinary drugs, among PFF in Chile. Two innovative indices were used, namely, the good practices adoption index (GPAI), and the good practices adoption rate (GPAR), as part of a national programme to reduce chemical residues in PFFs' primary products. The study of innovation dynamics is based on the recognition that farmers, or any actors in a particular agrifood chain, have a base knowledge prior to any intervention process, and so are themselves able to discover and develop new understandings and skills to improve their current performance and standard of living [6].

Peasant Family Farming

Peasant family farming is often not defined as such and the word "peasant" is usually excluded. The FAO defines family farming (FF) only as, "all family-based agricultural activities, including agricultural, forestry, fisheries, pastoral and aquaculture production which is managed and operated by a family and predominantly reliant on family labour" [7]. However, "peasant" refers to a social group and a traditional knowledge set that gives farmers identity and legitimizes their institutions, projects and demands [8].

FF is the predominant form of agriculture in the world, having an important socio-economic, environmental and cultural role [7]. Small-scale farmers produce over 70% of the world's food needs and contrary to the current perception, in nominal terms, the number of peasants and smallholders has increased [9].

Peasant family farming in Chile is of high importance for food security. It comprises more than 1.2 million people [10] and more than 260,000 farms of Chile, almost 90% of the farms in the country. It uses 38% of the irrigated surface and creates more than 60% of agricultural employment, including self-employment [11]. Family farmers produce 45% of vegetables, 43% of maize, wheat and rice [12], 54% of cattle, 42% of sheep, 94% of goats and 76% of honey bees [13].

At the national level, there are a number of factors that are key for the successful development of family farming, such as: agro-ecological conditions and territorial characteristics; the policy environment; access to markets; access to land and natural resources; access to technology and extension services; access to finance; demographic, economic and socio-cultural conditions; and, the availability of specialized education [7]. Proximity and networking with consumers, and differentiation (organic, artisan, local, fair trade, small producers, etc.) are also essential for success.

Working with smallholders is vital for their understanding of how practices involving antimicrobial use might influence resistance to veterinary drugs [14], and how the presence of residues of other drugs and pesticides can cause various problems in their communities.

2. Materials and Methods

The analysis presented in this study is based on qualitative information collected in the summer and autumn of 2017 in the regions of Valparaíso, Metropolitana, O'Higgins, Maule, Biobío, Araucanía, Los Ríos and Los Lagos in central and southern Chile.

Surveys

A survey was carried out among 247 peasants, distributed across the different regions and productive sectors as shown in Table 1. The number of participants in each survey was calculated proportional to the amount of smallholder farmers in each sector and region, using the following formula:

$$n = NZ^2 p(1-p)/d^2(N-1) + Z^2 pq \quad (1)$$

where N is the number of farmers in each productive sector and region; d is the precision, being 0.08; Z is the reliability, being 1.96; p is the proportion, being 0.25; and q is $1 - p$, so 0.75 [15].

Table 1. Surveys undertaken by region and productive sector.

Region of Chile	Productive Sector	Number of Surveys
Valparaíso	Beekeeping	16
Metropolitana	Vegetables (lettuce and tomatoes)	16
O'Higgins		19
Maule	Berries (raspberries and strawberries)	54
Biobío		20
	Beekeeping	33
	Dairy cows	29
Araucanía		12
Los Ríos		10
Los Lagos		38

The farmers who took part in the study participate in the extension services provided by INDAP, (The Agricultural development Institute of the Ministry of Agriculture of Chile), so meet several of the socio-economic characteristics, in terms of levels of income and land tenure [among others] that make them beneficiaries of these programs. INDAP has a huge network of extension services, for technical and economic assistance to PFF distributed throughout the territory. For this study, local networks and technical assistants of the eight regions allowed the working team to contact the farmers who participated in the surveys. The surveys were identified with a code linked to the farmers' names, which remained confidential as agreed with them.

The information used in this study was obtained from surveys conducted among PFF on GPs in the use of veterinary drugs and pesticides. The surveys were conducted to compare standard GPs with the actual practices carried out by the farmers. Measured GPs were related to adequate handling, use and storage of chemical products, as well as some information to identify the producers, including:

- **Identification of farmers and surveys**: full name, phone number, productive sector, region, location, technical assistant, program to which they belong, survey administrator name and date of survey.
- **Veterinary drug use**: exclusively for treating diseases and pests; prescribed by a veterinarian; maintain use record; record of animal or hive diseases; exclusively authorized formulations; following the instructions for dose, timing, length of the therapy and mode of administration; respect of withdrawal period; in respect of target species and stage of production.
- **Veterinary drug handling**: not used when expired, contaminated, or vial damaged; applying all the preventive and biosecurity measures needed for the premises; careful care and hygiene measures; appropriate infrastructure and implements; correct disposal of expired, surplus and empty packaging and materials.
- **Veterinary drug purchase**: from authorized stores, use of veterinary prescription if required, and **stored** in exclusive and locked compartment, keeping them in their original packaging, protected from light humidity and extreme heat or cold.
- **Pesticide use**: only authorized formulations; when approved by target markets; application programme; toxicological classifications are known; respect of target species and plague, disease or weed; respect of recommended dose, frequency of application, preparation and mode of administration; withdrawal and re-entry periods.
- **Pesticide handling**: adequate dosage area; qualified and accredited personnel; adequate personal protection items and security elements; correct after-use washing of application equipment and personal protection items; correct disposal of the remains of washing; correct disposal of empty packages.
- **Pesticide purchase**: from authorized stores, and **stored** according to manufacturer's instructions, in an exclusive and adequate storage room, adequate storage record.

The list of GPs used as the standard for this study is detailed in Tables A1 and A2 in Appendix A, for veterinary drug and pesticide use, respectively. The information to develop these GPs lists was obtained from national and international standards, and fed into the preparation of two sets of guidelines and two brochures, developed by the working team on good practices in the use of pesticides and veterinary drugs. The brochures were made specifically for producers and the guidelines were made for extensionists, authorities and specialists.

From the GPs lists, two surveys were developed to interview farmers and find out the percentage of GPs being adopted (Figures A1–A4 in Appendix A). The main topics contained in the material relate to the application, handling, storage and empty package disposal of veterinary drugs and pesticides. The guideline, brochure, GPs list and survey on pesticide use also include topics related to operator safety, preparation and environmental precautions.

All the survey data was transferred to a database where each of the items on the GPs lists were categorized as adopted, or not-adopted, for each farmer according to their survey answers.

Figure 1 shows the process of developing the material to measure good practices for pesticide and veterinary drug use in the PFF context.

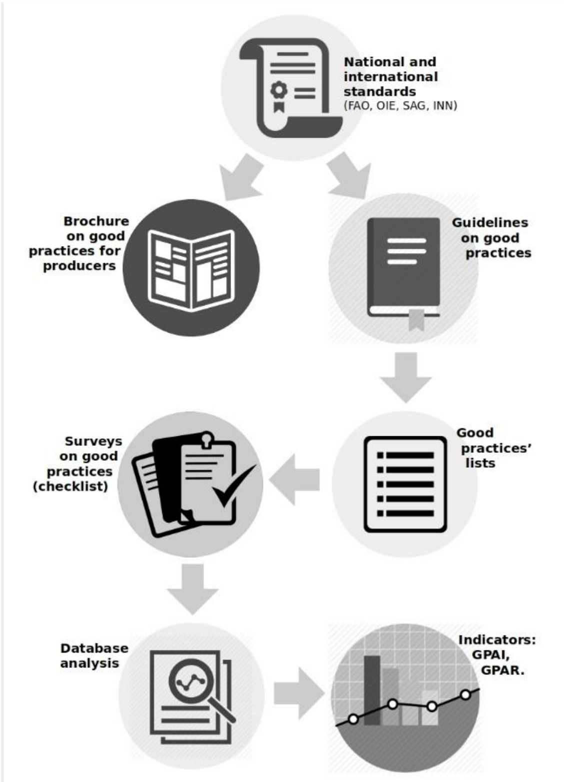

Figure 1. Origin and outcomes of good practice measures and training material.

The database information was used to quantify the GPs adoption level in each productive sector, using the innovation adoption index and the innovation adoption rate developed by Muñoz et al., 2007 [5] at the University of Chapingo, Mexico. These two indicators were adapted for use as the GPs adoption index (GPAI) and the GPs adoption rate (GPAR), and aimed to measure the following:

- **GPAI**: This index shows the percentage of GPs adopted by each surveyed farmer for veterinary drugs or pesticides. That is, the percentage of the 17 practices included in the checklist that were successfully adopted by each farmer. For example, a theoretical GPAI of 50% would be given to a farmer who adopted half of the practices in the checklist.
- **GPAR**: This rate shows the percentage of farmers adopting each GP from the total surveyed farmers of each productive sector. That is, the percentage of farmers who are successfully adopting practice #1, #2 . . . etc. For example, a theoretical GPAR of 50% would be given to GP #1 if half of the farmers adopted it.

3. Results

The results of the good practices adoption indices by each group (productive sector) are shown in the following graphs (Figure 2). Graphs (a) and (b) show the GPAI for veterinary drug for dairy producers and beekeepers respectively, distributed by those with a GPAI of less than 30%, 30–39%, 40–49%, 50–59%, 60–69%, 70–79% and greater than 80%. Graphs (c) and (d) show the same for pesticide use by vegetable and berry producers. For example, graph (a) shows that 16% of dairy producers adopted between 40% and 49% of the listed GPs for veterinary drugs.

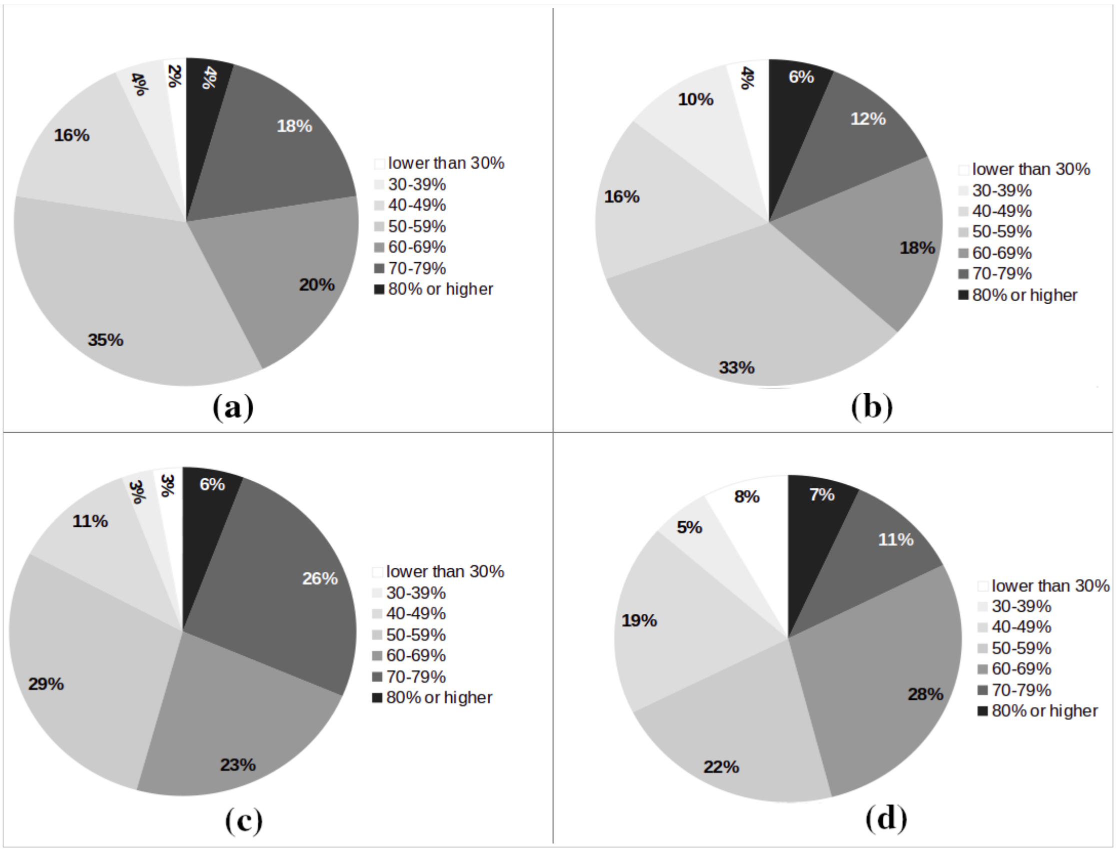

Figure 2. Good practice adoption index (GPAI): Percentage of GPs adopted by producers. (**a**) dairy producers; (**b**) beekeepers; (**c**) vegetable producers; (**d**) berry producers.

The indices show relatively high results, having group averages between 55% and 61%, while the overall average for all farmers who participated in the study is 57.33%. From the results by group it can be seen that in every group there are what could be called "advanced farmers", that is, farmers adopting 70% or more practices. These advanced farmers represent 18–31% of the farmers in all the groups. This tells us that every group has accumulated knowledge and has decoded the standards for good practices into peasant-specific terms so as to apply them in their production systems.

Also, it is clearly seen that most of the surveyed producers are in an intermediate situation regarding adoption of good practices, with 50–55% of producers adopting 50–69% of the good practices. Farmers adopting less than 30% of the practices are few, from 2% to 8% of the farmers in each group.

Tables 2 and 3 show the good practice adoption rates described and categorized by level of adoption. Low-adopted practices are the ones being adopted by 33% or less producers, mid-adopted practices are the ones being adopted by 34–66% of the producers, and high-adopted practices are the ones being adopted by 67% or more producers.

Table 2. Good practices adoption rate (GPAR): Level of adoption of good practices in veterinary drug use for dairy producers and beekeepers.

Level of Adoption	Practices
low-adopted practices (0–33%)	• animals/hives diseases record. • correct empty package disposal. • correct storage of veterinary drugs and other sanitary products. • acquisition of drugs with veterinarian prescription. • beekeepers: use of officially authorized drugs.
mid-adopted practices (34–66%)	• veterinary drugs application record. • follow the instructions given by the veterinarian in terms of dose, timing, length of the therapy and mode of administration. • application of drugs in the stage of production and species indicated by the manufacturer and/or the veterinarian. • application of disease prevention and bio-security measures to reduce the use of veterinary drugs.
high-adopted practices (67–100%)	• use of drugs recommended by the veterinarian. • dairy producers: use of officially authorized drugs. • respect of withdrawal period of drugs. • no administration of expired or contaminated drugs. • acquisition of drugs in authorized establishments. • storage of drugs in their original packaging, protected from light, humidity and extreme heat or cold.

Table 3. GPAR: Level of adoption of good practices in pesticide use for vegetable and berry producers.

Level of Adoption	Practices
low-adopted practices (0–33%)	• stored pesticides, responsible person and applicator records. • danger signage usage in pesticides storage room. • danger signage usage in field during and after application. • have complete personal protection items and equipment
mid-adopted practices (34–66%)	• use of officially authorized pesticides. • use of pesticides according to requirements of target markets. • pesticides used according to the cultivated species. • follow the instructions given by the technical assistant in terms of timing of application as well as preparation and storage of products. • knows and respects withdrawal and re-entry periods.
high-adopted practices (67–100%)	• the pesticide application calendar is made with the technical assistant. • farmer knows the general toxicological classification (colored circles) of pesticides. • technical recommendations are followed in terms of dose and plague-to-use pesticides. • pesticides room meets basic requirements and is isolated to prevent contamination from the outside. • calibration of pesticide application equipment is regularly made. • use of personal protection items to apply pesticides. • pesticide application record. • application equipment and personal protection items are washed after pesticide application.

The results of the adoption rates show that some practices of critical importance are mid- or low-adopted. Among these are: the use of officially authorized products in the case of beekeepers and agricultural producers, the acquisition of veterinary drugs with prescription, following the application instructions of the veterinarian and technician for pesticides, the application of veterinary drugs in the recommended productive stage, complete equipment and personal protection items for pesticide application, use of pesticides according to the cultivated species, and knowing and respecting withdrawal and re-entry periods.

As seen in the study of Pannell et al., 2006 [16], for the adoption of conservation agriculture practices, innovations are more likely to be adopted when they are perceived as having a high "relative advantage" and when they are feasible and replicable.

These advantages could mean the increase of certain outcomes, saving of certain expenses, resilience of the system itself, access to certain markets, or avoiding problems or penalties with certain authorities, etc.

Non-adoption or low adoption of innovations can be explained by their failure to provide a relative advantage, or a range of difficulties that farmers may have in trialing or replicating them.

The surveyed practices are frameworks from regulatory authorities that ensure that foods derived from animals treated with approved veterinary drugs are safe for human consumption [2].

Moreover, other tools that attempt to predict adoption of agricultural practices have been developed based on variables related to economics, risk, environmental outcomes, farmer networks, characteristics of the farm and the farmer, and the ease and convenience of the new practice, thereby including characteristics of both the practice and the potential adopters. The "ADOPT" model attempts to predict the adoption of agricultural practices by putting several questions to users related to characteristics of the practice, the people influencing their perceptions of the relative advantage of the practice, the ease and speed of learning, and their ability to learn about the practice [17].

4. Discussion

In order to improve GPs among family farmers, assessing these practices and establishing their level of adoption was a necessary first step. To this end, the GPAI and GPAR indicators were constructed in order to visualize and analyze actual GPs adoption by the groups of farmers, and the topics for which the adoption was the lowest. This served as a baseline and orientation for the technical talks and working groups.

GPs in peasant family farming have been assessed by Dhayal et al., 2015, Panell et al., 2006 and Muñoz et al., 2007. These authors worked with farmers groups and described levels of adoption of agricultural conservation and production practices [6,16,18]. Cofré et al., 2012 performed a GPs adoption analysis on fresh fruit producers of Chile [19], but a systematic effort has never been undertaken with smallholder farmers until this study.

The specific methodology used to obtain the results in this study was taken from Muñoz et al., 2007, but the good practices and innovations adoption approach has been widely used in social analysis of rural environments, learning approaches in agricultural practices, and farmers' networks of knowledge, among others [4–6,16].

When analyzing the results, the case of beekeepers stands out. It is fair to say that an important reason for the use of non-authorized chemical substances for beekeeping is the lack of authorized alternatives for the treatments against the *Varroa destructor* parasite, the main sanitary problem for bees in Chile. Only two active principles are authorized (flumethrin and amitraz), with two and one commercial formulations respectively, and another commercial formulation with an organic controller associated with natural essences [20]. Despite the above, it is also true that efforts regarding environmental and handling practices to reduce the incidence of this parasite in hives are usually not made and almost all health care is entrusted only to chemical substances for disease control. Moreover, evidence has been put forward on the effect of pesticides on immune suppression, and therefore increased susceptibility of honeybees to pathogens, specifically neonicotinoids and phenyl-pyrazole (fipronil) [21,22], being the latter substance a common unauthorized insecticide used in beekeeping.

The results of this study show that in all groups there are farmers who have a high level of GPs adoption, and they constitute the "advanced farmers" of each group. Farmers create group solutions based on experimentation and learn mainly from other farmers [23]. Therefore, in the case of GPs adoption, all that would be needed is to mobilize the knowledge among peasants' trust-based networks, and that would constitute an efficient and effective way to increase the adoption of GPs.

Farmers understand and trust in someone with similar values, language and origins to them who can show and prove (and not just tell or teach them) how to improve, as they mostly learn by experimentation and pair-demonstration [23]. This has been called "social learning" by many authors [5] and is defined as an interactive process where knowledge is shared and co-constructed (or co-decodified in this case) within interactions, and not transferred by experts [24]. Being a group and empirical process, social learning involves reflecting on experiences, ideas and values, searching for a holistic understanding of problems, and collaborating in order to deal with conflicts [25].

Adoption of innovations or good practices depends on a range of personal, social, cultural, environmental and economic factors, as well as on characteristics of the innovation itself, and takes place when the farmers perceive that certain innovations will enhance the achievement of personal goals regarding their production system [14]. Some characteristics of farmers have a positive and significant relationship with the adoption level of innovations, such as age, education, family size, annual income, social participation, source of information, knowledge, scientific orientation, economic motivation and proximity to urban areas [26]. Factors external to farmers, such as farm size, production system, access to credit, and government incentives are also mentioned as important variables associated with the adoption of innovations [27].

Extension services technicians also play a key role in GPs adoption by farmers. Their training should include communication skills with farmers and adult education methodology. Efforts at this level are being made in *INDAP,* which provides a course on this topic to extension personnel with the support of the University of Chile, UC Davis and *Universidad Austral de Chile* [28]. Their role in farmers' technical training on GPs is also of high importance and this is being continuously applied in Chile by the extension programs *PRODESAL, SAT, Alianzas Productivas, PDTI*, among others [13].

Nowadays, rural networks in Chile also include technical assistants, veterinary authorities and products and services providers, so the success of GPs adoption also depends on their participation in building awareness [3].

5. Conclusions

These results show that there is an important gap in GPs adoption in the use of veterinary drugs and pesticides among PFF. Important practices have a low adoption rate and many farmers are below the average GPAI. As stated before, the good news is that every group of farmers has some high GPs adopters, and they are the ones who can share and transfer their experience and knowledge among other farmers.

Changes in the conceptions of extension and rural innovation require new training strategies for rural extensionists. There is a need for expanding, reframing and overcoming the traditional transfer-of-knowledge approach, focusing on reflective practice process, supporting the horizontal exchange of knowledge and experience, and facilitating the development of producers and extensionist communities of practice. Also, it is important to systematize innovative training practices and research on training for extensionists and their impact [23].

Another related term for transforming conventional agricultural research and extension, and including farmers' knowledge and insights on indigenous practices, is sharing knowledge [29]. This is described as a process with deep roots in the experiences of rural people striving to retain dignity, self-confidence and influence over their future [30]. Facilitating space for farmers' own reflection on their practices and farmer-to-farmer learning, experimentation and development of their own solutions is also vital for their continuous improvement, adaptation, autonomy and subsistence.

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Appendix A

Table A1. Standard good practices (GPs) for the use of veterinary drugs in peasant family farming.

	Veterinary Drugs
1	Veterinary drugs must be applied only for treating diseases. Preventive functions are restricted exclusively to vaccines and diagnosis for diagnostic toolkits.
2	Antibiotics must not be applied as growth promoters.
3	Animals or hives presenting diseases must be recorded and kept updated.
4	Veterinary drugs can only be applied when prescribed by a veterinarian.
5	Veterinary drugs can only be applied to the individual(s) or hive(s) they were prescribed for.
6	Only veterinary drugs registered by the official veterinary service (in Chile SAG, *Servicio Agrícola y Ganadero*) can be applied.
7	Instructions given by the veterinarian must be followed in terms of dose, timing, length of the therapy and mode of administration.
8	The withdrawal period of the drug, as indicated by the manufacturer and/or the veterinarian, must be respected.
9	Veterinary drugs must be applied in the stage of production and to the species indicated by the manufacturer and/or the veterinarian.
10	A veterinarian must be contacted in case of doubt in the use of a veterinary drug or suspected adverse reaction.
11	Drugs with damaged vials, or which have expired, or are contaminated should not be used and be discarded.
12	Disease prevention and biosecurity measures must be applied to reduce the use of veterinary drugs: Careful care, hygiene and appropriate infrastructure and implements must be used, to strengthen the animals' and hives' immune condition and ensure prevention of exposure to determinants of disease.
13	Veterinary drugs must be purchased in an authorized pharmacy or veterinary/agricultural products store.
14	When required, veterinary drugs must be bought with a veterinary prescription.
15	Veterinary drugs must be stored in an exclusive compartment, locked, and in the charge of a person responsible for them.
16	Veterinary drugs must be stored in their original packaging, protected from light, humidity and extreme heat or cold (read the label of the packaging to see the storage conditions for each drug).
17	Expired and surplus drugs, empty packaging and materials used for the application of drugs (e.g., syringes) must be disposed of by keeping them in a clearly identified container, and removed by a specialized company.

Table A2. Standard GPs for the use of pesticides in peasant family farming.

	Pesticides
1	Only pesticides registered by the official agricultural service (in Chile SAG, *Servicio Agrícola y Ganadero*) are applied.
2	Only pesticides approved by the target market are used.
3	Pesticide application programs are made with a technician or professional assistant.
4	Toxicological classification and dangers of pesticides are known.
5	Pesticides are applied only to manufacturers' recommended species.
6	Pesticides are applied only to manufacturers' recommended plague, disease or weed.
7	Manufacturers' or technicians' recommended dose, frequency of application, preparation, mode of administration, withdrawal and re-entry period are followed.
8	Pesticide storage recommendations are followed.
9	Pesticides room is used only for pesticides, has a solid and closed ceiling and floor, and is well-illuminated and ventilated, with proper danger signage and description of stored products.
10	Pesticides room has a stock record that includes types, quantities and person responsible for pesticides.
11	There is an exclusive pesticide dosage area used only by qualified personnel, with adequate personal protection items and security elements (fire extinguisher, anti-spill products, emergency shower, first aid kit, etc.).
12	The person in charge of pesticide application has an up-to-date applicator credential.
13	Personal protection items are used during pesticide application.
14	Application equipment is calibrated, and application and re-entry field signs are used.
15	Records of the applicator's name, date, name of pesticide, and dose are maintained and up-to-date.
16	After pesticide application the application equipment, personal protection items and empty phytosanitary packages are washed and disposed of properly.
17	The remains of washing are disposed of in vacant areas, away from water courses and inhabited areas. Empty packages are taken to a specific collection center.

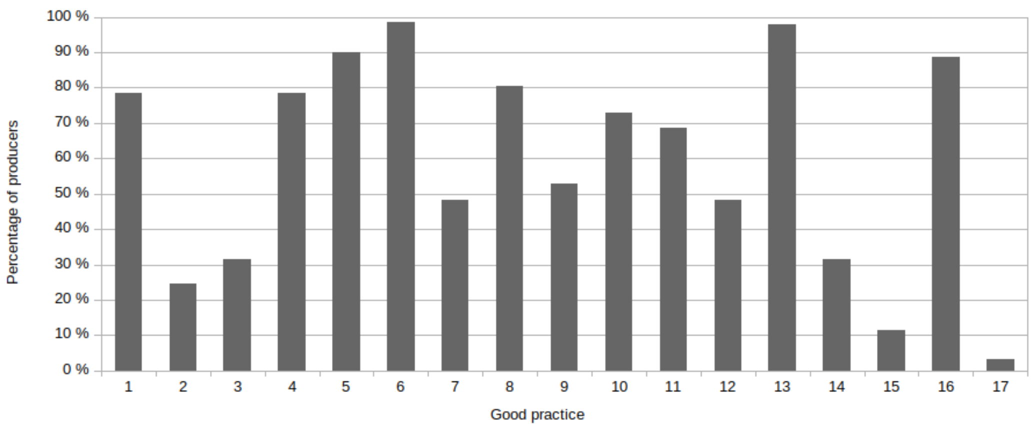

Figure A1. Percentage of dairy producers adopting each GP.

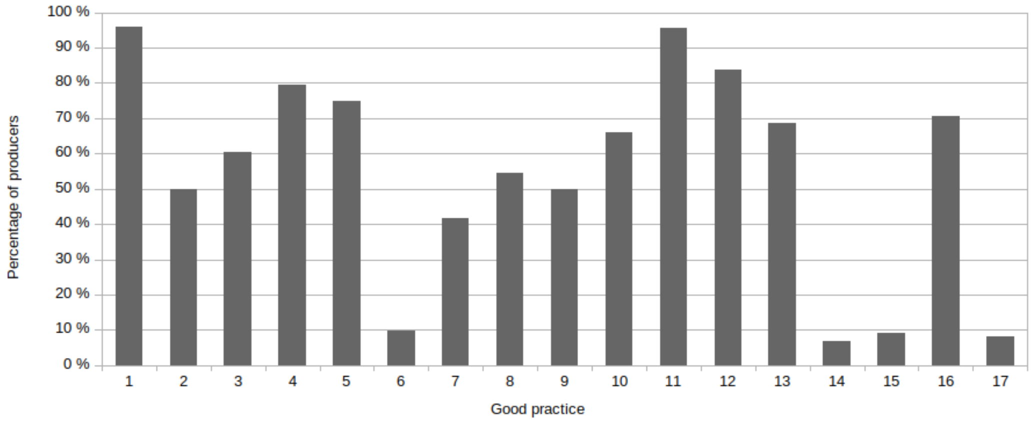

Figure A2. Percentage of beekeepers adopting each GP.

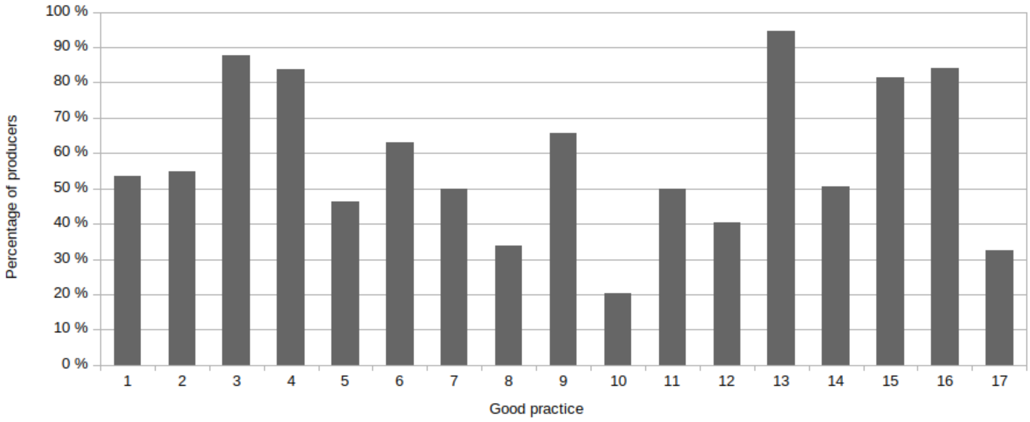

Figure A3. Percentage of berry producers adopting each GP.

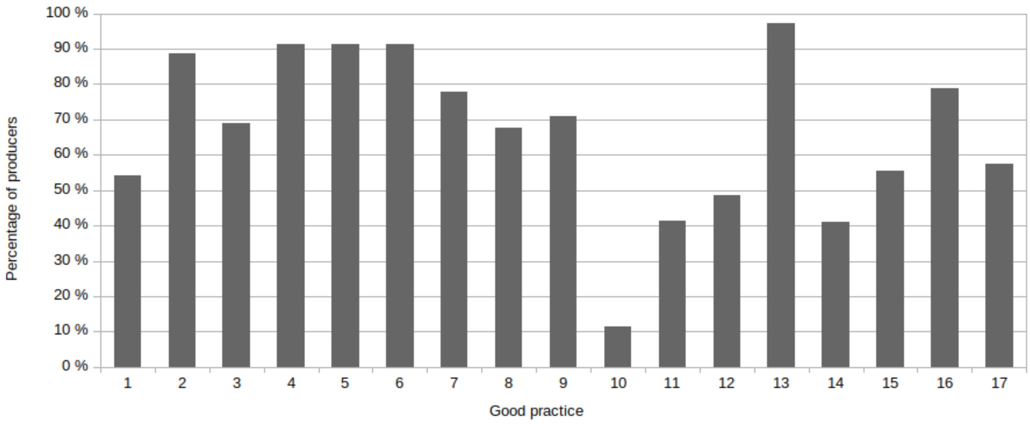

Figure A4. Percentage of vegetable producers adopting each GP.

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