Keeping goats or going north?

Enhancing livelihoods of smallholder goat farmers through brucellosis control in Mexico

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This research was conducted under the auspices of the Graduate School of Wageningen Institute of Animal Sciences (WIAS)

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Thesis
submitted in fulfilment of the requirements for the degree of doctor
at Wageningen University
by the authority of the Rector Magnificus
Prof. Dr M.J. Kropff,
in the presence of the
Thesis Committee appointed by the Academic Board
to be defended in public
on Monday 25 August 2014
at 11 a.m. in the Aula.

Oseguera Montiel, David
Keeping goats or going north? Enhancing livelihoods of smallholder goat farmers through brucellosis control in Mexico
150 pages.
PhD thesis, Wageningen University, Wageningen, NL (2014)
With references, with summaries in English, Dutch and Spanish
ISBN: 978-94-6257-034-4

In memory of my father Francisco Javier (1938–2008) and of my auntie Lulú (1941–2013).
Dedicated to my mother Maru, my loving wife Eliza and my boys Antonio Ariel and Cristóbal

My utopia is peace in this world, I believe that poverty alleviation is a must to achieve peace. I hope that this piece of work can contribute to eliminate poverty in Mexico and in other parts of this planet where smallholder goat farmers struggle to make a living.

CONTENTS

ABSTRACT

Smallholder Mexican farmers are embedded in an adverse context, due to neoliberal globalization policies, which threatens their livelihoods, and has caused an unprecedented surge of migration to the US. Keeping goats is one strategy to diversify livelihoods. Goat husbandry is dairy oriented and has a range of functions for farmers, like income, food, insurance, credit, and a reason for not having to migrate to the US. However, caprine brucellosis, a zoonosis endemic in Mexico caused by *Brucella melitensis*, has a negative impact on flock productivity. Although brucellosis is rarely a fatal disease in humans, it can be very debilitating and disabling due to complications such as arthritis and spondylitis. The main objectives of this thesis were to assess the impact of brucellosis on smallholder goat husbandry and to evaluate brucellosis control strategies in enhancing farmers' livelihoods. The research approach was that of a case study, incorporating methods from natural and social sciences, such as archival and secondary data review, surveys, ethnography and veterinary epidemiological modelling. The case study was conducted in two states within the Bajío region with high rates of migration: Michoacán and Jalisco. In Michoacán free cost vaccination and testing was applied whereas in Jalisco farmers had to bear part of those costs and there was a lack of veterinarians offering the service. Goat farmers considered that they were better off than farmers who did not keep goats: 'it is better to herd than to be herded'. Farmers' knowledge, labour and good social capital allowed them to maintain relatively large flocks given the amount of crop land owned. The prevalence of testing positive to brucellosis in goats was 38% in Jalisco and 11% in Michoacán. Access to communal land and crop residues were key for the pastoral management system prevalent in the study area, but grazing goats had higher risk of testing positive to brucellosis. Farmers avoided drinking goat milk, as it was seen as a cause of 'fever'. The milk price was low and controlled by the caramel industry. Vaccination and test-and-cull strategies are options to control brucellosis. Simulations showed that vaccination is economically feasible but will not bring the prevalence below to 10% within 5-years. Test-and-slaughter is not economically rewarding at the current milk price. At present, culling of seropositive goats to brucellosis does not happen because an adequate infrastructure for culling does not exist. Farmers perceived that brucellosis control measures cause losses such as abortion due to untimely vaccination and infections due to ear tagging. Moreover, farmers did not always know that brucellosis and Malta fever (human brucellosis) are synonyms, neither were they aware of all consequences of brucellosis infection. Brucellosis control is stagnant because of a two way lack of communication: farmers are not well informed about brucellosis and policies are formulated without knowledge of goat farming practices and of farmers' perceptions. Successful brucellosis control would enhance smallholder goat farmers' livelihoods but the control policy needs to be redesigned. Important factors to consider in the design of a new policy are: (1) a comprehensive compensation for losses when applying test-and-cull; (2) the integration of farmers' expertise and experience; (3) diffusion of knowledge about brucellosis control, its prevention and its impact on human health and livestock production; (4) a regional planning is a must to succeed.

1

INTRODUCTION

1.1 BACKGROUND

GOATS AND LIVELIHOODS

The number of poor people at global level remains high despite the millennium goal to reduce poverty by half in 2015 (Global-Issues, 2011). Poverty is more prevalent in rural areas where people depend on farming. In the global South three of every four people in poverty are from rural areas (Banco-Mundial, 2007). Agriculture, however, is still considered an instrument for poverty alleviation (Banco-Mundial, 2007). It has been suggested that livestock can play a role in poverty alleviation, in particular goats (Devendra and Chantalakhana, 2002; Lebbie, 2004; Peacock, 2005). Goats are found in a range of agroecological conditions worldwide. The bulk of the goat population is found in the low-medium income countries of the global South (Morand-Fehr et al., 2004). Goats have multiple roles in the livelihoods of the rural poor. Table 1.1 shows a diversity of goat husbandry characteristics in several regions of the world. Often goat management systems are based on grazing, ranging from mixed sedentary systems to nomadic systems. Zero-grazing and tethering systems are common amongst smallholders keeping small flocks ($<$ 10 head) as is the case in Indonesia and Ghana (Budisatria et al., 2007a; Duku et al., 2010). In areas where pastoral and agro-pastoral systems are common, flocks are larger, as for example in the north of Argentina (Paz et al., 2005), north of Mexico (Escareño, 2010), and south of Spain (Castel et al., 2003).

Meat and dairy outputs from goats are a food source in many countries (Table 1.1). Other products, such as mohair and cashmere are important in Central Asia (Medeubekov et al., 2008) and manure is important in Indonesia (Budisatria et al., 2007a). Next to these products goats also have socio-economic and cultural functions for people. Goats are liquid assets that can be sold to cover school and crop expenses and other emergencies such as hospital fees (Perevolotosky, 1990; Hernández et al., 2001; Duku et al., 2012). Bosman et al. (1997) showed that the capital asset function was four times higher in monetary terms than the meat production of dwarf goats in West Africa. Cultural-religious roles are also present in ceremonies for Rarámuris (an indigenous group in the north of Mexico) (Rincón Gallardo, 2011) and for Muslims in Indonesia (Budisatria et al., 2008). In Benin, both the cultural role of goats and as income source for women are important (Dossa et al., 2008).

In harsh arid and semi-arid conditions goats have been shown to be well adapted (Iñiguez, 2004; Lebbie, 2004). One of the advantages of goats is that they are excellent browsers, which allows them to depend less on grazing in pastoral systems. When grass quality declines goats can eat shrubs instead (Yayneshet et al., 2008), and this capacity to shift from grazing to browsing is superior compared to cattle and to sheep (Sanon et al., 2007; Jonsson, 2011). It is also suggested that goats kept in extensive grazing systems can change their diet, e.g. from shrubs to grasses, according to their physiological needs, i.e. lactation and pregnancy (Mellado et al., 2005). Goats are also good climbers and can 'stand' with their hind limbs in a 'bipedal' position to access tree foliage (Animut and Goetsch, 2008). In addition they are adapted to digest vegetation with a relatively high content of tannins (Hofmann, 1989). Hofmann classifies goats as 'intermediate grazers' due to their capacity to browse and graze. Intermediate grazers have a well developed mobility of their lips that allows them to eat leaves from shrubs.

Donor agencies and governments have funded goat projects for poor people in need. Various factors affect the success of these programmes, such as experience with farming

Table 1.1: Goat husbandry products and functions, flock and region characteristics in various countries around the world

Product/function	Flock characteristics: size (head), breeds	Management	Region and characteristics	References
Dairy production and goat kids, income	Size range 29-163; breeds, Criollo, Saanen and Anglo Nubian	-	Semi-arid, Santiago del Estero, northeast Argentina	Paz et al. (2005)
Dairy production and goat kids, income	Size range 14-190, mean 68; crossbreds of European breeds	Extensive grazing	Coahuila, north Mexico, arid climate, rainfall 250 mm	Escareño (2010)
Manure, saving	Mean 6, breed Etawah	Confinement and some grazing	Kulungprogo, Indonesia uplands $>$ 500 meters above see level	Budisatria et al. (2007a)
Meat, milk and blood, income, security, rites, dowry	Size range 51-66, breeds Hamer, Malle, Borana, Dasenech	Pastoralism, agro-pastoralism	South Omo, Ethiopia, arid and semiarid. rainfall 350 to 1400 mm	Tekleyohannes et al. (2012)
Dairy and meat	Size range 129 - 220, breeds Malagueña, Murciana–Granadina (dairy), Serrana and Blanca Andaluza (meat) and Payoya and Florida (mixed)	Grazing and mixed grazing	Andalusia, south Spain, Mediterranean climate $\sim$800 mm rainfall	Castel et al. (2003)
Cashmere and Mohair	Breeds Kazakh Down (Cashmere) and Kazakh (Mohair)	Pastoral systems	Kazakhstan, arid and semi-arid	Medeubekov et al. (2008)
Meat, cash, religious	Size range 6 - 7	Grazing, tethering, zero-grazing	Ashanti, Ghana, rainfall 1200 - 1500 mm	Duku et al. (2012)

(Rigada Soto and Cuanalo de la Cerda, 2005; Budisatria and Udo, 2013), institutional support, veterinary services and information (Peacock, 2005; Budisatria and Udo, 2013). In Indonesia, goats have been used as a credit in kind to victims of natural disasters to rebuild their livelihoods (Budisatria and Udo, 2013). The Indonesian programme was successful with two-thirds of the farmers and contributed significantly to the income of the household.

Poor management in goat husbandry can have a negative impact on people's livelihoods. For example, too high goat densities can cause soil erosion and land degradation due to overgrazing. In Indonesia, inadequate goat manure management was found to pollute groundwater (Budisatria et al., 2007b). Goat diseases can cause severe economic losses. Goat kid mortality as reported by Ramírez-Bribiesca et al. (2001) can have direct economic consequences for farmers. In addition, some goat diseases can be transmitted to humans and may have serious health consequences for them, an example being caprine brucellosis, also known as Malta fever. This disease causes financial losses to goat farmers, mainly due to goat abortion. This might counteract the potentially positive impact of goats on livelihoods. In Mexico, brucellosis is endemic in the goat population which hinders both goat production and affects human health (Luna-Martínez and Mejía-Terán, 2002; SSA, 2014). Box 1 gives an example of the impact of brucellosis for a farming family.

BRUCELLOSIS

Brucellosis is an ancient zoonosis – most likely present in humans for at least two-millennia (Capasso, 2002) – that occurs in animals and humans worldwide, mostly in low and middle income countries (Pappas et al., 2006). Brucellosis in humans can be treated with antibiotics, but no vaccine is available to protect humans from infection. Hence, a strategy for control and eradication of brucellosis in animals is considered to be the most effective way to reduce the incidence in human populations. In the late nineteenth century *Micrococcus melitensis* now named *Brucella melitensis* was isolated from a British soldier's spleen who had died from 'Malta fever' now known as brucellosis (Bruce, 1887 cited by Godfroid et al., 2005). It was thought to be a vector-borne disease until about hundred years ago when Themistocles Zammit, a Maltese doctor, isolated *B. melitensis* from milk of apparently healthy goats and discovered it was the cause of human brucellosis (Seleem et al., 2010).

Currently, eight *Brucella* species are identified (Sriranganathan et al., 2009), six in terrestrial animals: *B. abortus* (cattle), *B. melitensis* (small ruminants), *B. ovis* (sheep), *B. suis* (pigs), *B. canis* (dogs) and *B. neotomae* (mice) and two in marine mammals: *B. cetacea* and *B. pinnipediae*. *Brucellae* are in general host-specific but cross-species infections may occur, which means for example, that *B. melitensis* can be transmitted from goats to cattle, pigs, dogs and others, and conversely goats can be infected with *B. abortus* (Alton, 1987; Corbel, 2006). In a retrospective study covering data from 1994 to 2006 in Argentina, isolates in human cases were attributed to *B. melitensis* (145), *B. suis* (144), *B. abortus* (75), and *B. canis* (3) (Lucero et al., 2008). *B.melitensis* is considered the most pathogenic species in humans.

Box 1: Impact of caprine brucellosis on a farming family in Mexico
Juan is a smallholder goat farmer what we call a *chivero* in Mexico. He lives in a village of the Bajío region, is a small land holder (1 ha) and owns a goat flock of 70 head; which was bought with his savings from temporal migration (3-year period) in the United States. Juan and his wife have three daughters and two sons. The flock is a source of weekly income, he sells goat milk to the prosperous caramel industry. His oldest son is his right hand with the daily work. Juan is not fully fit for the job especially for carrying heavy loads (sacks of feed 40 kg.). He never recovered the normal strength on his back after being affected by brucellosis –a zoonosis– which is transmitted from goats to humans. I asked him whether goat husbandry has aided his family to become less vulnerable or to gain wealth. His answer was: 'it would have been different if I had not got the disease [brucellosis], I had at one point 120 does...(*lo que me atraso a mi fue la enfermedad*) what put me back was the disease [brucellosis]'. To get the right treatment for brucellosis was an *Odyssey*. He was first affected in one of his legs which he could not move. Physicians thought that he had a problem with his sciatic nerve. Soon after his other leg was affected, he could not walk and he was in bed for two months and sweating and fever were also present. Juan thought that he was going to die. He was listed for spine surgery. Fortunately for Juan and his family a close relative persuaded Juan's family to refer him to a clinic in a another town. There, he was diagnosed with brucellosis. He started to recover soon after, the treatment lasted two months. If he would have been admitted to surgery, it would have cost him ca. 72 thousand Mexican pesos (equivalent to 6 thousand US$, this is what he was told to be ready to pay); a fortune for a smallholder in Mexico, whereas the brucellosis treatment –mostly antibiotics– was about 3 thousand Mexican pesos (250 US$). Still Juan's family had to sell goats, land and other savings to pay for a range of bills during the period when he was not diagnosed correctly. In 2008 it was confirmed that brucellosis was endemic in his flock.

Source: interview by D. Oseguera Montiel, Labor Vieja village, Jalisco, Summer 2009

Brucellosis ranks as one of the five most important zoonotic diseases in many countries of the global South (Figure 1.1). Brucellosis does occur in humans from non-endemic countries, but in most instances brucellosis has been acquired while travelling in countries where brucellosis is endemic. In Germany in 2002 and 2003, 30 people were diagnosed with *B. melitensis* and one was affected by *B. suis* (Al Dahouk et al., 2005).

Although brucellosis is rarely a fatal disease in humans, who are accidental hosts, it can be very debilitating and disabling (Franco et al., 2007). The treatment often consists of using two types of antibiotics for about six weeks (Memish and Balkhy, 2004). A general symptom of brucellosis is undulant fever, but complications such as arthritis and spondylitis are common, in women abortion may occur and in men orchitis; less frequent complications are being observed in the cardiovascular and central nervous systems (Pappas et al., 2005; Corbel, 2006). Complications occur because brucellosis infections are often not timely recognised, because one of the early symptoms, fever, is a symptom of many other infectious diseases such as, influenza, typhoid fever, malaria and dengue. Physicians are not always alert to suspect brucellosis in patients presenting fever (Al Dahouk et al., 2005), osteoarticular involvement, e.g. spondylitis, paravertebral abscesses (Dalmak et al., 1996; Ben-Ami et al., 2000) and abnormal

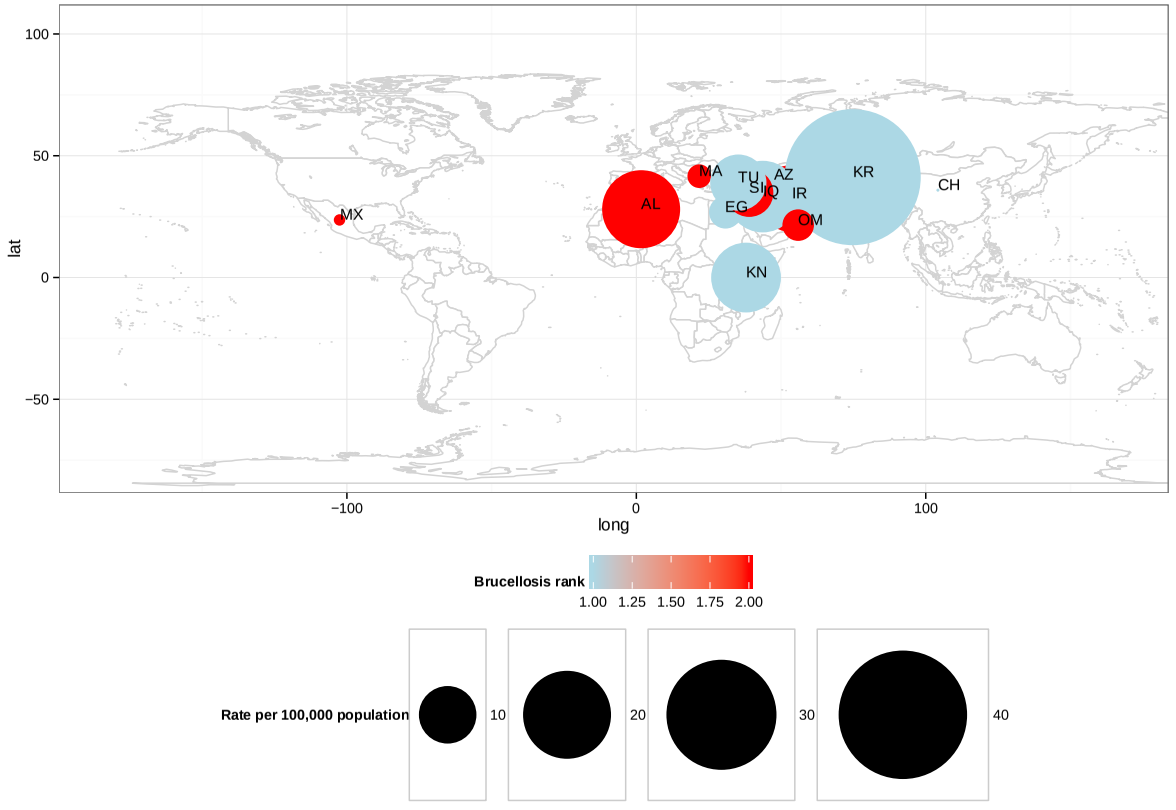

Figure 1.1: The worldwide distribution of brucellosis. AL = Algeria, AZ = Azerbaijan, CH = China, EG = Egypt, IR = Iran, IQ = Iraq, KN = Kenya, KR = Krygystan, MX = Mexico, OM = Oman, MA = Republic of Macedonia, SI = Syria, TU = Turkey. Incidence in humans and rank when compared to other zoonoses within each country in 2013, except for Egypt (2012) and Kenya (2008). Data source: (OIE, 2013)

neurological symptoms, e.g. double vision, uveitis, panic attacks (Vogt and Hasler, 1999; Garnica et al., 2010). People become infected through the consumption of unpasteurized dairy products (i.e. soft cheese, milk, ice cream, butter), blood, uncooked liver and spleen, having contact with infected animals and through the intake of aerosolized bacteria (Pappas et al., 2005). Person-to-person transmission is rare, but may occur by sexual contact, blood transfusion or transplants (Corbel, 2006).

Brucellosis is endemic in domestic animals in most low and middle income countries and in central and southern European countries (i.e. Portugal, Spain, Italy and Greece) (OIE, 2004; Memish and Balkhy, 2004). Cross-species infections are a challenge in developing countries where smallholder farmers may keep a range of animal species (Holt et al., 2011). In non-endemic countries wildlife may be a reservoir of *Brucella* (Melzer et al., 2007). Transmission between animals occurs through direct and indirect contact with infected animals or fomites. Most common infection routes are ingestion of bacteria from fomites, contamination of abraded skin, wounds and mucosal surfaces, and natural breeding (Corbel, 2006).

The economic impact of a disease can be classified as direct and indirect (Rushton et al., 1999). Direct impacts of caprine brucellosis are twofold. First, goats will have a lower performance. Following Corbel (2006), *Brucella* pathogens manifest in the reproductive organs of goats. In females, the infection may induce placentitis which results in abortion in the last third of pregnancy. Infected goats often abort only once and subsequent pregnancies can be normal. Brucellosis is also associated with premature births and placenta retention. Premature births and abortion are negatively related to milk production. In bucks, brucellosis can cause epididymitis and orchitis, which has a negative impact on fertility. Second, brucellosis impairs human health and may lead to disability. Treatment and diagnosis demand economic resources, e.g. antibiotic treatment for six weeks at least. Furthermore, expensive and hazardous procedures, e.g. fine-needle spine aspiration for diagnosis may occur when physicians fail to diagnose brucellosis at the onset (Ben-Ami et al., 2000). Indirect economic impacts in goat production relate to the costs for prevention and control, such as vaccination, testing and surveillance. Added to these, an indirect economic impact is the lower value of infected animals. Therefore, the economic benefits derived from brucellosis control are estimated to be high. In Mongolia US$18.3 million was estimated to be gained through a 10-year mass vaccination of livestock, the benefits derived due to the combined effect of livestock productivity and lower incidence of human brucellosis (Roth et al., 2003).

Given its impact on human health, and on livestock production, brucellosis is a notifiable disease to be reported to the World Organization of Animal Health (OIE) (OIE, 2014). The *Terrestrial Manual* by the OIE outlines which serological tests and vaccines should be used in the control of brucellosis and how they should be manufactured (OIE, 2009). Brucellosis eradication can be achieved through vaccination and subsequent test-and-cull. In small ruminants the vaccine to be used is Rev 1, a live attenuated vaccine developed in the late 1950's (Blasco, 2010). A time lapse of about a year is needed between vaccination and testing to avoid culling false positive animals (Alton, 1987) as the standard serological tests, Rose Bengal Test and Complement Fixation Test, cannot differentiate between antibodies raised by vaccination or by natural infections.

Blasco (2010) recommends the use of vaccination for about 6-12 years as a first phase of brucellosis control to lower *B. melitensis* prevalence in small ruminant populations. Vaccination with vaccine Rev 1 has been successfully applied to reduce brucellosis prevalence in

small ruminants in Tajikistan (Ward et al., 2012). Eradication of the disease requires a test-and-cull strategy which is usually implemented after a first phase of control by vaccination. In northern Europe test and culling policies have been successful partly due to farmer cooperation because they were compensated for culled animals (Godfroid et al., 2013). The risk of re-introduction of brucellosis in free countries is real and surveillance systems need be implemented to detect the disease before major outbreaks occur (England et al., 2004).

BRUCELLOSIS CONTROL IN MEXICO

As brucellosis is worldwide a notifiable disease, Mexico developed a regulation, mandatory for cattle and small ruminant keepers, to combat brucellosis (SAGARPA, 1996). Despite that almost 20 years have elapsed since the regulation for brucellosis was launched in 1996, the disease is still endemic in most regions of the country, eradication showing almost no progress between 2000 and 2012 (cf. Luna-Martínez and Mejía-Terán, 2002; SENASICA, 2012). Furthermore, human brucellosis cases do still occur. The official number of human cases fell at national level (in 2007: 3,008 cases and in 2013: 2,035) (SSA, 2014); however, the real incidence is most likely much higher, because the surveillance system in Mexico is passive. In rural communities, poor people often lack good medical services and patients may not get diagnosed and hence escape the statistics. Smallholders are usually at higher risk of contracting zoonotic diseases, because they often live in close contact with their animals. In Mexico 60% of the goat population spends the night next to farmers' houses (INEGI, 2007).

1.2 THE GOAT HUSBANDRY SECTOR OF MEXICO

A variety of goat husbandry management and objectives are found across the country. Goat densities, management and production objectives vary according to the ecosystems and markets for goat products. In Mexico four ecological zones are identified, arid and semi-arid, temperate, subhumid tropical and humid tropical. The arid and semi-arid zone represents about half of Mexico (CONAGUA, 2014) and it is where the highest density of goats is found. In the mountainous region of Chihuahua, a northern state, goats are kept in transhumant systems for meat consumption and hides are used for making drums by the Rarámuris (Rincón Gallardo, 2011), whereas in the semi-arid zone of San Luis Potosí goats are kept in transhumant farming systems, where cheese production is an important income source and the flocks range from 10 to 200 head (Mora-Ledesma, 2011). In the southern states, Oaxaca and Puebla, *Criollo* goats (mixed breed) and crossbreds with Nubian goats are kept for meat production. In temperate areas of Puebla, goats are tended in extensive grazing systems with a median of 27 goats per flock (Vargas López, 2003; Jiménez Mendoza and Sánchez Ortega, 2009). A small number of commercially oriented farms ($\sim$ 22) in the state of Guanajuato are producing soft cheese, which is marketed in supermarkets, and gourmet restaurants and hotels (CONARGEN, 2011). In other states in central west Mexico such as in the Bajío region of Michoacán and Jalisco goat husbandry is common for meat and milk production (Díaz Gómez, 1995).

According to the most recent census, the goat population is approximately 4 million, kept by about 260 thousand households (INEGI, 2007). Although INEGI's estimates do not distinguish between large, medium or small farm sizes, it can be inferred that the bulk of the goat population is owned by smallholder farmers because the use of external inputs is limited to

12% of the flocks (INEGI, 2007). In this group, 92% invest in vaccines, 76% in antihelmintics, 16% in concentrates and 11% in technical assistance. The goat population has been declining during the last decades. Between 1991 and 2007 the population was halved and the number of goat farmers reduced to 40% (INEGI, 1991, 2007). This is probably a reflection of the agricultural crisis of the country which has been aggravated due to the neoliberal policies which have been applied since the late 1980's (Bartra and Otero, 1988) and which favour large-scale intensive agriculture. Mexico has become also less self-sufficient in food production because fewer farmers are cultivating the land (Barkin, 1987). Yet, smallholders are resilient and there is a reconfiguration of smallholder agriculture where farmers are combining different activities, e.g. temporal migration and off-farm jobs to sustain their living (Keilbach Baer, 2004).

1.3 HISTORICAL BACKGROUND OF GOAT HUSBANDRY IN MEXICO

COLONIAL PERIOD: LATE FIFTEENTH CENTURY TO EARLY NINETEENTH CENTURY

Goats were first introduced by the Spaniards in the country in the sixteenth century during the conquest. The goat breeds introduced were Blanca Celtibérica and Murciana Granadina (CONARGEN, 2011). Soon after their introduction, goats, sheep and cattle populations grew exponentially (Braudel, 1984), mainly due to the abundance of natural feed sources (Chevalier, 1963). The Spaniards established large agricultural estates known as *'haciendas'* (Chevalier, 1963). The Spanish Crown granted land to the Spaniards as '*estancias de ganado mayor y menor*'; (large and small livestock land farms) (Esparza Sánchez, 1988).

In the Bajío, our study area, goat husbandry was the most important farming activity (Rabell, 1986). Goats were used to clear off the shrub-land because the land had never been cultivated (Baroni Boissonas, 1990). Goats were kept in extensive grazing systems. Meat, hides and fat were the most important outputs. It was the second most attractive activity for the conquerors after mining (Esparza Sánchez, 1988). Sheep took over soon after the wool industry developed within the region in the first quarter of the eighteenth century (Rabell, 1986). The second half of the eighteenth century was characterised by diversification of agriculture. Food demand for the mining sector was a main driver for more intensive cropping systems based on irrigation. The agro-ecological conditions (river basin area from the Lerma river, fertile soils and a relatively good pluvial precipitation that averages $\approx 700mm$ annually) allowed two cropping cycles in a year; rainfed maize in the spring-summer - the rainy, warmer period - and irrigated wheat in the autumn-winter - the dry and cooler period. Infrastructure for irrigation systems (i.e. ditches, dams, canals) was built to realise two cropping cycles per year (Baroni Boissonas, 1990).

Maize and wheat cultivation were the most prominent activities by the end of the eighteenth century. The Bajío was soon renowned as the 'granary of Mexico' due to its high level of grain production. The production of wheat yield was 2 to 3 times higher than in Europe (Palerm, 1980, cited in Baroni Boissonas, 1990). The Bajío had a strategic location connecting to the north and the heart of Mexico and to the ports of the Gulf of Mexico in the south. The Bajío was a grain provider for the more densely populated central parts of Mexico and for the mining industry within the Bajío and in the north of Mexico. Small ruminants' meat and fat for candles were important inputs for the mining sector.

EARLY INDEPENDENCE PERIOD: NINETEENTH CENTURY

The beginning of the nineteenth century marked the end of the colonial period. The railway infrastructure was developed and trading of agricultural commodities with the US was enhanced. The Bajío remained as one of the most prominent agricultural regions but cattle and equines became more prominent than small ruminants because they were needed for draught power in land cultivation (Rabell, 1986). After independence, the land was still kept in the few hands of *hacienda* owners. The number of people without land was high and many of them were badly in debt with the hacienda owners (Meyer, 1986).

REVOLUTION AND POST-REVOLUTION PERIOD 1910 TO 1970'S

By the end of the nineteenth century most Mexicans lived in poverty. This triggered the Mexican Revolution in 1910, *Tierra y libertad* (Land and Freedom) were the claims. One of the achievements of the revolution was a land reform. The land reform created the *'ejidos'* (communal holdings) and private smallholdings allowing smallholders the right to 'own' land. The land reform started to be implemented in the Bajío communities in the 1930's. By the first half of the twentieth century the number of goats in the country was over 5 million (DGE, 1932). From 1935 to 1965 the agricultural sector had one of the greatest growths in history. This period is characterised by the implementation of the import substitution policy, which aimed to replace foreign imports with domestic production. Agriculture became a source of raw materials for the food industry. In the 1960's goat husbandry had governmental support, which was more evident in the northern states where goat density has been highest in a region called la Laguna. In Durango state, a caprine breeding center and a plant to process goat dairy products were built by the government (Cruz Castillo, 2005). Spanish breeds, such as Blanca Celtibérica for meat production and Murciana Granadina for milk production were still very abundant at the start of the 19^{th} century in northern states (Echeverría, 1960, cited in Gómez y González et al., 2009). By the 1960's the goat population consisted of mainly Criollo goats, which are well adapted to harsh environmental conditions (Sierra et al., 1997).

1980'S AND EARLY 2000'S

This period is characterised by the global market policies that follow the dictates of the World Bank and the International Monetary Fund. For Mexico these policies led the state to leave the food commodities to the market and to dismantle subsidies, infrastructure, research and extension. In 1994, Mexico signed the North American Free Trade Agreement (NAFTA), and tariff barriers for food commodities such as maize and milk were eliminated. The new market-based model aimed to reduce debt, inflation and currency instability. Results, however, were harsh for the rural poor. A drastic drop in agriculture employment has been observed in the last 25 years. Mexico lost 20 per cent (2.1 million) of its agricultural jobs between 1991 and 2007. Non-salaried agricultural family employment declined 58 per cent between 1991 and 2007 (Wainer, 2013). Many displaced farmers, and in particular young people, migrated to the cities or to the US. About one fourth of rural Mexicans aged 15 – 24 in 1990 had left their villages by 2000 (Wainer, 2013). The caprine center of Durango was closed (Gómez y González et al., 2009). In the 1990's the first Boer goats were imported (CONARGEN, 2011). Other exotic dairy breeds were also introduced, such Saanen, Toggenburg, and French Alpine, which are popular in the Bajío, as well as Nubian and La Mancha. The Nubian is popular in Nuevo León state for goat kid meat production. The Spanish breed

Murciana Granadina is considered to be at risk of disappearance in Mexico (CONARGEN, 2011).

1.4 THE STUDY AREA

The study was carried out in villages of the Bajío region, which comprises areas of four of the central states of Mexico: Guanajuato, Querétaro, Michoacán and Jalisco. This study focuses on the border area of the Michoacán and Jalisco states (Figure 1.2). The area has a relatively good road infrastructure and intensive high input irrigated agriculture is common. The land is used to grow maize, wheat, sorghum, beans, tomato, chili and agave. The temperature of the region varies from 18 to 22 °C and annual rainfall averages 700 mm. The rainy season is during the summer months: July to September. The dry period is longer, from October to June. In general, the land in the valleys has a good crop potential, but availability of good land is rarely available for smallholder farmers, who often have to cultivate marginal land in the hills where the crop potential is low.

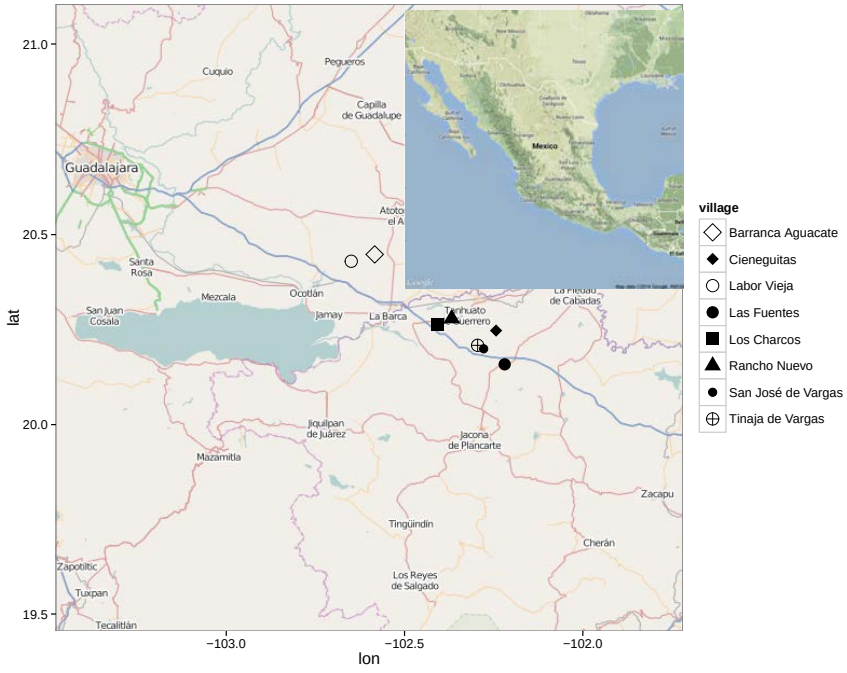

Figure 1.2: Map showing the study area and villages

The human population growth in the study region is either negative or low, ranging from -8% in San José de Vargas to +1% in Labor Vieja. One of the causes for this negative/low population growth in rural villages of Mexico is migration due to lack of jobs and poverty (Wainer, 2013). From 1995 to 2000 about 1 million 600 thousand Mexicans migrated to the US,

and from 2005 to 2010, about 600 thousand. The latter drop in migration was due to tougher US border control; illegal migration is highly risky and expensive. About forty percent of Mexico's international migration is from rural communities (Burstein, 2007), and Michoacán and Jalisco have one of the highest rates of emigration to the USA. In addition, the current violence due to drug cartels is another reason for families to migrate.

1.5 PROBLEM STATEMENT

Goat husbandry has potential for poverty alleviation and rural development (Devendra and Chantalakhana, 2002; Lebbie, 2004; Peacock, 2005). Smallholder goat farmers, however, are often operating in a complex context characterised by unfavorable policies, e.g. limited access to subsidies and credits. They also face competition with better subsidized producers from abroad (Barkin, 2006). Furthermore, neoliberal policies – which are geared towards enhancing industrial farming, export products, biofuels, and genetically modified crops – are having a negative impact on the continuity of smallholder farming worldwide (Altieri, 2009). This leads to the debate of the future of smallholder farming agriculture in Mexico. On the one hand the *campesinitas* (peasantists) argue that smallholder agriculture will not disappear and on the other hand the *decampesinistas* (depeasantists or proletarianints) argue that smallholder agriculture has no future (Kay, 2008). Such debates are vital as smallholder agriculture may have an effect on important issues such as population growth, migration, sustainable food production and poverty alleviation (van der Ploeg, 2013). If goat husbandry is a promising strategy for smallholders, how can goat husbandry help smallholders in the unfavorable context characterized by neoliberal globalization? Furthermore, brucellosis can put farmers' livelihoods at risk because it not only reduces livestock productivity, but also threatens human (farmers') health. Brucellosis control seemingly is a neglected issue by scholars involved in small ruminant production. In recent scientific international meetings on goats there was only one paper on brucellosis presented (cf. IGA, 2008, 2012).

Brucellosis is endemic in the goat population of Mexico, including the Bajío region (Luna-Martínez and Mejía-Terán, 2002; González Navarrete and Mendoza Ángel, 2006). Quantitative data in regard to brucellosis, like the prevalence in humans and animals, are essential to plan strategies for brucellosis control (Smits, 2013). Next to epidemiological data, cost-benefit analyses of control measures are also important to take sound decisions about brucellosis control strategies. Such strategies are for example, vaccination and "test-and-cull". In general, test-and-cull strategies for brucellosis control employed in Western countries have not been followed in the global South. This could be related to the costs and the poor organisation of control programmes and/or lack of resources for control programmes (Luna-Martínez and Mejía-Terán, 2002; Blasco, 2010). Godfroid et al. (2013) postulate that eradication of brucellosis is almost impossible in the global South. However, knowledge on costs and benefits is lacking. Under which circumstances can test-and-cull be used? This information is needed before control and eradication policies can be developed in a country or a region.

To understand why brucellosis control programmes have not been successful in countries such as Mexico, it is important to consider farmers' and other stakeholders' perspectives. What is the opinion of farmers about brucellosis? Do they see any incentive to control brucellosis? What are the barriers? Is the impact of caprine brucellosis on flocks and human health understood? In-depth studies on what farmers think and know about brucellosis are

crucial to prevent a mismatch between control policies and their implementation at farmers' level.

The main objectives of the research described in this thesis were to assess the impact of brucellosis on smallholder goat husbandry and to evaluate brucellosis control strategies in enhancing farmer's livelihoods. The specific objectives were:

1. To describe the livelihoods of smallholder goat farmers
2. To explain the risk factors related to caprine brucellosis
3. To explore the economic benefits derived from brucellosis control
4. To understand the barriers for brucellosis control at farm level

In meeting these objectives, caprine brucellosis control strategies that match farmers' realities may be designed .

1.6 APPROACH AND METHODS

The approach chosen was a case study because it is best suited to understand caprine brucellosis in a complex context. The case study was conducted in two states within the Bajío region: Michoacán and Jalisco. The study initially focused on villages of Michoacán. Later, during the field work it was decided to include villages in Jalisco, because the two states share an area that is interesting with regard to brucellosis control – trading of goats and goat products between both states is common, but the implementation of brucellosis control measures is different between the two states. The methods used belong to a range of disciplines from animal science and social science (Table 1.2). In Chapter 2, quantitative data, obtained by means of surveys, and qualitative data, obtained through ethnographic methods, were used to gain a better understanding of smallholder goat husbandry in a complex context. In particular, it enabled to identify the impact of goats on people's livelihoods, which also provided a solid background to better understand the success or failure of brucellosis control strategies. The livelihoods approach is a framework that has been used frequently in development studies (Ellis, 2000). Emphasis is on the poor who are often at the center of the analysis (DFID, 1999). The approach can also be useful in assessing the impact of caprine brucellosis and control strategies for smallholder farming in Mexico.

The study was conceived to follow the 'DEED' framework, acronym of Description, Explain, Explore and Design. DEED was in principle intended to enhance the role of science in natural resource management based on an interdisciplinary approach (Giller et al., 2008). In this thesis the DEED framework is used as follows:

Chapter 2 describes the role of goat husbandry in the livelihoods of the smallholder goat farmers. This chapter contributes to the debate about the future of smallholder agriculture in the current socio-economic context marked by the neoliberal globalization. Chapter 3 explains the prevalence and risk factors of brucellosis in goat husbandry systems using veterinary epidemiological methods. How extensive is brucellosis in the goat population? What are the risk factors? Did the brucellosis campaign have any effect on reducing brucellosis prevalence? In Chapter 4, an economic evaluation of brucellosis control is presented. How profitable are control measures, i.e. test-and-cull, and vaccination? Chapter 5 explains farmers behaviour in adopting brucellosis control strategies. Why may farmers disagree with the

Table 1.2: Methods used in the study

Chapter	Science/discipline	Methods
I	Animal and social sciences	Mixed methods: qualitative and quantitative such as, surveys (i.e. longitudinal, cross-sectional) secondary data review, ethnographic methods (i.e. in-depth semi-structure interviews, participant observations)
II	Animal/veterinary science (epidemiology)	Serological survey among goats
III	Animal/veterinary science (i.e. health economics, epidemiology)	Epidemiological and economical modeling
IV	Social and animal sciences	Mixed methods: same as in chapter I

policy and the implementation of brucellosis control? Chapter 6 contributes to the design of an effective brucellosis control policy.

2

'IT IS BETTER TO HERD THAN BE HERDED': MAKING A LIVING WITH GOATS IN THE BAJÍO REGION, MEXICO

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A slightly different version is published in *Pastoralism: Research, Policy and Practice, 2014, 4:9 doi:10.1186/s13570-014-0009-2*

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ABSTRACT

Goats are renowned for their resilience in harsh environments and their relatively low investment for maintenance. Goat husbandry is thought to be a tool for poverty alleviation. Empirical evidence of this is scant. This research analysed the role of goat husbandry in supporting the livelihoods of smallholders of Michoacán in the Bajío region, Mexico. The Bajío is renowned by the good cropping potential of the land, smallholder goat husbandry is present too but largely unstudied by scholars and ignored by policy makers. The smallholders in the study area deploy a range of assets, natural, physical, social, human, and financial in goat husbandry. Their goat husbandry is dairy oriented; it is a source of weekly income, insurance, and a reason for not having to migrate to the US. Farmers' relatively good social capital allows them to access cheap crop residues and take turns for herding flocks. The goat dairy market, however, is controlled by a powerful caramel industry. In turn, the margins farmers obtain are rather limited. The nutritional value of goat milk is not exploited in their households as it is seen as a 'fever' cause, related to brucellosis. Qualitative and quantitative methodologies are based on the sustainable livelihoods approach linked to actor-oriented approaches. The study revealed smallholders agency by engaging in goat husbandry to deal with a complex institutional and political context led by economic liberalisation intertwined with local realities such as the local agroecology. We emphasised the importance of these findings in the development strategies for small-scale goat husbandry systems.

Keywords: Actor-oriented, Ejido, Goat husbandry, Michoacán, Neoliberalism, Smallholders, Sustainable livelihoods

2.1 BACKGROUND

Goat husbandry is considered to have great potential to improve the livelihoods of poor people (Sinn et al., 1999; Devendra and Chantalakhana, 2002; Lebbie, 2004; Peacock, 2005; de Vries, 2008). Compared to cattle, goats, are easier to raise in resource-poor households. This is because goats are resilient animals that can cope with relatively low quality feed and scarce water (Morand-Fehr, 2005). In the global South goat husbandry produces more value than single-sided production-economic criteria. Goat husbandry plays a role in financial security, women's empowerment, and insurance (Bosman et al., 1997; Dossa et al., 2008). Furthermore, goat husbandry exemplifies smallholders' agency, referring to smallholders' capacity to act and make choices. Smallholders' agency is often in response to an adverse context for smallholders, which in Latin America is partly the result of the neoliberal policies promoting free trade, privatization and deregulation among others.

Under the neoliberal paradigm Mexican smallholders are portrayed as backward or inefficient and hence the rhetoric that Mexico needs a 'modern' agricultural sector (Toledo, 1992). Smallholders are often deemed as the 'nonviable' (Bebbington, 1999). And therefore the way forward for neoliberal planners is to intensify and modernize the agricultural sector. For example, in 1992, the Mexican government, arguing that rural smallholders lacked productivity, launched the counter-land reforms that opened the door for seizing '*ejidos*'– smallholders community owned land which was about half of the agricultural land until 1991. This policy resulted from the negotiations of the North American Free Trade Agreement (NAFTA) (Schmidt and Gruben, 1992). Furthermore, public funds for the smallholder sector, in the form of subsidies and extension services, were withdrawn and BANRURAL (a farmers' bank) and CONASUPO (an institution to guarantee fair crop market prices) were dismantled. Under NAFTA there has been an unprecedented growth of commercial food corporations with oligopolistic control of food commodities (Ochoa, 2013). This context for rural smallholders is further complicated by the unprecedented wave of violent crime often related to drug trafficking (Pereyra, 2012). And yet smallholders are still resisting this hostile context. On-farm and off-farm diversification has been a main survival strategy in Latin American countries (Kay, 2008).

In Mexico, small-scale goat husbandry is one of these on-farm diversification strategies. Goats can be found across the country (INEGI, 2007). Although goat husbandry started during the Spanish colonization in the 16^{th} century little is known about the role of goat husbandry in contributing to smallholders livelihoods. It might be a good option particularly among rural poor people to fight poverty which affects approximately half of the population (CONEVAL, 2009). This paper aimed to study small-scale goat farmers' agency to make their living in a complex context, by using a sustainable livelihood framework that integrates actor-oriented approaches. We argue that small-scale goat husbandry is functional and well adapted to the agroecological conditions of the Bajío region, a relatively prosperous cropping area in central Mexico with a relatively large number of goats. We also unravel the threats and opportunities involved in small-scale goat husbandry as a livelihood strategy. In the following sections we present the theoretical framework and methods, and the historical background within which goat husbandry currently operates in the region. There follows an in-depth analysis of how goat husbandry has adapted to the local context and contributes to smallholders' livelihoods.

2.2 THEORETICAL FRAMEWORK

We used the sustainable livelihoods approach (SL) to analyse how smallholder goat farmers generate livelihoods in their specific agroecological and socio-economic context. A livelihood comprises: "[A]ssets...activities and the access to these (mediated by institutions and social relationships) that together determine the living gained by the individual or household" (p.10 Ellis, 2000). Assets or capitals for smallholders are natural capital comprising communal land grazing, water and crop land; physical capital comprising tools, machinery, infrastructure (e.g. roads, railway) and livestock; social capital comprising reciprocity, associations, cooperation and trust; human capital comprising people's skills, knowledge, health, education and traditional knowledge transmitted through generations; financial capital comprising money stored in a bank or at home, and credits or loans (Chambers and Conway, 1992; DFID, 1999; de Haan, 2000; Ellis, 2000).

Mapping out capitals according to different socio-economic strata of households can help to identify where pro-poor support can have impact (Bebbington, 1999). Socio-economic strata are often identified on how households themselves define being poor, in relation to their assets (Kristjanson et al., 2007), however, households' capabilities can be important too in defining well-being by households. Capability refers to being able to eat well, dress, to live without shame and have a social life among others (Chambers and Conway, 1992). Furthermore, it refers to being able to respond to shocks or stress, but also in being proactive by taking up opportunities to enhance their livelihoods such as, making use of information, collaborating with others, experimenting, and using new resources and services (Chambers and Conway, 1992). This study tries to understand the role of goats in terms of households capitals and capabilities.

Capitals can be converted to other forms of capitals and there are tradeoffs on how capitals are used (DFID, 1999). For example, goats, a natural capital, can be used to generate outputs like meat, milk and manure, which are often a source of income (Ellis, 2000). Goats are liquid assets to be used in times of cash need, so for smallholders goats are an insurance (Bosman et al., 1997). Goat management, however, can also lead to the destruction of other capitals. By way of example, in Indonesia goat manure is a valuable output for cropping by enhancing land fertility a natural capital, but at the same time manure is piled up near settlements and pollutes ground water (Budisatria, 2006).

Access to capitals is central in understanding livelihoods while reflecting how policies and institutions affect access to capitals is also important (DFID, 1999). In access to capitals, politics and power relations play a role. As such 'a livelihood is organized in arenas of conflicting [and] co-operating actors' (de Haan and Zoomers, 2005, p.34). Yet, politics have been overlooked in livelihood studies (Scoones, 2009). Politics relate to how macro policies (e.g. neoliberal globalisation in Mexico) and power relations among actors affect the access to capitals. In the Mexican rural context different actors often collide and intertwine (Long, 1998). Drawing on these concepts we postulate that goat husbandry is a livelihood strategy adapted historically to its specific context and that goat keeping households employ a range of capitals, the access to which is influenced by the context. This refers to the institutional and political context in which goat husbandry is embedded, such as the agroecology and everyday relations of farmers among themselves and with other actors.

2.3 STUDY SITE

AGROECOLOGICAL CONDITIONS

The study was conducted in northern villages of Michoacán, a part of the Bajío region which is a relatively large area that encompasses territories of four central states (Michoacán, Guanajuato, Querétaro and Jalisco) of Mexico (Chávez-Torres, 2005). The region is characterized by plains interrupted by multiple hills and volcanoes. The altitude ranges from 1,000 to 2,000 meters above sea level, rainfall average is 800 mm and most precipitation is during the summer period (June - October). Ambient temperature averages 20°C. The Bajío region is a river basin area that has a high crop production potential, with irrigation in some areas. Land is cultivated for maize, sorghum, wheat and now notably cash crops (vegetables and fruits) in greenhouse systems for export to the US (Chambers et al., 2007). Two main forms of cropping can be found: high input industrial agriculture, and traditional low input crop production (González-Martínez, 1992), a pattern present since colonial times where irrigated wheat was the predominant crop (Chambers et al., 2007). Smallholders cultivate maize, sorghum, wheat, chickpeas on rainfed marginal land as well as on high potential agricultural land, mainly for self-consumption (by humans and animals), but as cash crops too. Besides cropping, smallholders are also engaged in seasonal wage labour, livestock husbandry and temporal migration to the US. The region has one of the highest rates of out-migration to the US in the country (Arias and Mummert, 1987).

HISTORIC CONTEXT OF GOAT HUSBANDRY IN THE REGION

Goats were introduced by the Spaniards in the 16^{th} century during colonization. In this period the goat population had an exponential growth, due to the abundance of feed sources, grazing land and crop residues (Braudel, 1984). Spaniards seized indigenous peoples' land, became the *Haciendas*– huge farms. In the search for more crop land Spaniards moved to the Bajío where goats were used mainly to clear off the vegetation for later land cultivation (Baroni Boissonas, 1990). Then goats became the most prominent livestock species (Rabell, 1986). Goat meat was also a food source for workers of the mines and goat fat was used to make candles for the mines of the region. In the 18^{th} and 19^{th} centuries when cropping became an important activity in the Bajío, cattle outnumbered goats. This was linked to the development of more sedentary farming systems (Rabell, 1986). Goats were kept in extensive grazing systems and cared by hacienda workers (Zendejas-Romero, 2003).

By the 1930s some haciendas were dissolved and the land was distributed among smallholders who were entitled to work a plot of land in a so called *ejido* system. Currently, in the Bajío region small-scale goat husbandry based on extensive grazing management is relatively popular, especially in villages of Chapala lake basin area and the Lerma river. Goat milk is the main input for *cajeta*–similar to the English caramel. The *cajeta* industry plants are found in the region. Smallholders keeping goats are colloquially known as *chiveros*. Goat meat has a local market for a popular dish called *birria*.

2.4 METHODOLOGY

The field work was conducted in two periods: (1) February to July 2007 and (2) from May 2008 to July 2009. A snowball technique (Biernacki and Waldorf, 1981) was used to identify

villages where small-scale goat husbandry was present. In the first period, villages of Tanhuato and Ecuandureo municipalities were visited. Semi-structured interviews gave a better understanding of goats multifunctional roles and farmers' constraints. We approached smallholders herding their flocks and appointments were made for interviewing. Secondary data was sought to understand the history of goat husbandry in the region. Two cross-sectional surveys were carried out in four villages, Cieneguitas, Los Charcos, San José de Vargas and Tinaja de Vargas from the municipality of Tanhuato. The first survey was used to characterize smallholders' livelihoods assets by their socio-economic strata. In this survey we also investigated how goat husbandry was valued by households; this included identification of the different functions represented in goat husbandry and smallholders' other strategies.

Goat keepers were subdivided into three wealth groups: 'poor', 'medium' and 'better-off'. In conjunction with an NGO employee who had been working directly with goat farmers to control brucellosis, a key informant was identified within each village to help sort fellow villagers into the wealth strata. From a census by the NGO a list was obtained with names of the head of the household and his or her number of goats. The second survey aimed to understand the views of goat farmers' neighbours about goat husbandry. A random sample of 145 households was interviewed using a questionnaire with closed questions.

The second part of the study involved a longitudinal survey and qualitative methods. The purpose of the survey was to calculate the gross margins of goat husbandry and crop production. Data about inputs and outputs of crop and goat production of the year were obtained from 18 farmers. Farmers recorded the information in notebooks, which were then collected on four occasions throughout the year. Gross margins were calculated as the difference between the outputs, such as crops, milk, goat kids and the inputs, for example, fertilizers, sprays, feed, vaccines, wormers and antibiotics. The contribution of goat husbandry and cropping to cover a family's basic necessities (e.g., food, housing, health, education) was evaluated by comparing gross margins with the poverty threshold in rural Mexico which is 15,384 Mexican pesos (MX$) (US$ 1,251) per year per capita CONEVAL (2009). Milk price was also compared to inflation in Mexico from 2006 to 2008.

Qualitative methods involved ethnographic observations in households, milking sites, grazing areas, farmers' meetings, and milk collection. We also used rural appraisal techniques; such as group discussions about goat husbandry versus temporal migration to the US (three group discussions), mapping and transects (three completed), semi-structured interviews with farmers (n = 19) and stakeholders (n = 10), and informal talks among smallholders and stakeholders.

Quantitative data was described with R (R, 2014) and ggplot2 was used for graphs (Wickham, 2009). Interviews were generally audio-recorded, or else notes were taken. Audio-recorded interviews (ranging from 1 hour to 2 hours) were fully transcribed in Spanish. Qualitative analysis was done by (1) coding material, (2) identifying themes, and by (3) describing and exploring themes. We used Weft QDA for coding (Fenton, 2006).

2.5 RESULTS

CAPITALS STATUS OF DIFFERENT GROUPS OF SMALLHOLDER FARMERS

Table 2.1 shows the distribution of some of the capitals across the wealth groups. Better-off goat keepers had on average 15 ha of cropland (1^{st} and 3^{rd}) interquartiles (IQ) 11 - 21).

Table 2.1: Descriptive statistics of farmers' assets and household characteristics according to their strata. Source: cross sectional survey (2007)

	median	IQ[a]	mean	SD[b]	N[c]
Land (ha)					
Poor	2.0	1.0 – 2.5	2.0	1.2	14
Medium	5.0	4.0 – 7.0	5.8	2.6	21
Better-off	15.5	11.0 - 21.0	15.8	9.2	8
Goats (n)					
Poor	30	22 - 45	37	21	17
Medium	70	32 - 123	91	83	23
Better-off	107	80 - 154	131	87	8
Household size (n)					
Poor	5	3 – 6	5	2	17
Medium	5	4 – 6	5	2	23
Better-off	4	4 – 6	5	2	8
Age household head (y)					
Poor	49.5	44.5 - 54.0	50.0	12.1	16
Medium	51.0	39.0 - 64.0	50.2	13.7	23
Better-off	39.5	36.3 - 58.3	45.6	16.7	8

[a] interquartile range
[b] standard deviation
[c] number of households

Most of this land was of higher quality, located in the valleys, leveled and some plots had irrigation. Most of these farmers had large flocks, on average 131 goats (80 - 154 IQ). These farmers invariably had a truck and a tractor. The poor and the medium wealth groups had less of the above capitals. Poor households had on average 37 goats (22 - 45 IQ). Two-thirds of the households in the poor group owned 2 ha of land on average (1 to 2.5 IQ). Poor households crop land was often in communal areas and was known as *ecuaros*; which were plots of $\sim$ 1 ha in the edges of the hills. The medium wealth group had on average 90 goats (32 to 123 IQ). They owned relatively better crop land than the poor and on average they owned 6 ha of land (4 to 7 IQ). There were however, landless farmers in these two groups too (n = 3 in poor and n = 2 in medium). Two-thirds of medium farmers had a truck and 15% had a tractor, whereas only a quarter of poor farmers had a truck and only one poor farmer had a tractor.

There were no differences among wealth groups in household size age of the household head (Table 2.1). Despite the similar size of the households, health status, migration, and age of children played a role determining the wealth stratum of the household. Households were classified as poor when the head of the household (a man) was unfit for physical work due to

illness. For example, one household deemed as poor had three children in their teens, ∼0.75 ha and 45 goats. The man, however, was uncapable to do any work as he was in wheelchair. Relatively young married couples with infants, absence of the man (head) due to migration to the US and being hired as labourers were other reasons given to classify households in the poor group. Two-thirds of the households reported having more than ten years of experience in goat husbandry, regardless of their wealth group.

There was a range of social capital forms among households. It was remarkable the companionship that derives in sharing responsibilities for herding goats. Some households also engaged in entrepreneurial activities such as growing alfalfa (one farmer with irrigated land and another with financial assets). In one of the villages farmers constantly communicated to help each other during herding, often to find lost animals or share news, using walkie talkies. The form of social capital also differed among the wealth groups. The medium and better-off groups for example made strong ties with some of the personnel from the NGOs. An NGO person could be invited to have lunch at their houses. In return, these households could have their flocks vaccinated first.

There was a history of rivalries between families of two villages which weakened social capital at community level. This rivalry had led a record of deaths in both villages. During the field study for example, farmers from one of the villages reported they felt oppressed by an extended family from the neighbouring village. These farmers were often insulted by this family. "They also come at nights to dare our children", the farmers reported. For some farmers the situation was unbearable and they fled because of fear of violence against them or because of direct death threats. Two extended families migrated to nearby villages together with their goats, but were unable to harvest their crops any more. Three other households sold their flocks and tried to make their way elsewhere.

The wealth ranking exercise showed how goat farmers perceived their well-being. In general, farmers considered themselves to be better-off compared to those having no goats (physical capital). Figure 2.1 shows that goats were not just an income source. Security was also important. Having goats was a guarantee of access to credits in their village. '[W]ith a small flock one can defend better than one who owns nothing..being a goat farmer you always have one or two *pesos* [5] in your pocket'. 'You are what you have, if you have goats you can get credits, if you only have land you will not get them. [The logic of the lender is].. [a farmer] will not sell land to pay but he will sell goats" (farmer, San José de Vargas). In the group discussions it was stated that having a flock was also a way to be your own boss and not to be fully dependent on being a hired labourer *'mas vale arrear que ser arreado'* (it is better to herd than be herded). Furthermore some job offers were not acceptable. Farmers reported that they were hired to apply a lot of chemicals in cropping (e.g. pesticides and herbicides), long workdays (15 hours) and wages were not good either. Farmers also benefit by having *birria* (the local goat meat dish) at their disposal. About 11% of the male goat kids were for self-consumption. Farmers could also please friends or relatives with a birria dish for special occasions such as in childrens' graduations from primary or secondary school. Goat male kids were also given as gifts; about 14% of the male goat kids were given to friends or to neighbours to thank them for allowing the goats to graze their crop residues.

For some senior farmers goat husbandry was the base for accumulating other capitals (i.e. land and cattle). The best example of this is a handful of extended family households,

5 Mexican currency

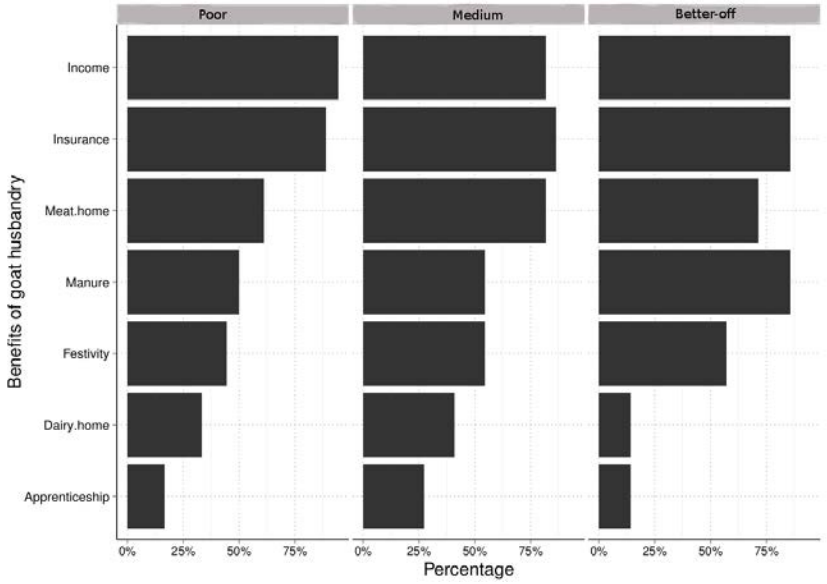

Figure 2.1: Goat husbandry functions according to farmers' views (n = 46)

who have managed to consolidate relatively large flocks $\geq$ 400 equal to 30 goats per capita. Farmers reported that their parents had started with just a handful of goats. Among farmers who managed to consolidate large flocks, especially middle-aged farmers, migration to the US was not considered an option. One said "I am happier here with my goats" (farmer, San José de Vargas). Young men however, with a small flock ($<$ 15 goats) and low crop production potential were relatively eager to migrate.

LIVELIHOODS STRATEGIES PORTFOLIO

Figure 2.2 shows that households engaged in a range of activities to sustain their livelihoods besides goat husbandry. The range of activities tended to be wider for households in medium and better-off groups. Cropping was the most frequent reported activity across the three wealth strata of households. External inputs were used to crop, fertilizers, seeds, sprays, hire labour, diesel, machine hiring and transportation. Therefore, households in particular farmers in medium and better-off groups sought to get credits to cultivate land. Households grew for the market and for home consumption. In general, only households in the better-off and medium groups could grow for the market (sorghum and maize). Land with less cropping potential was used for cropping for home consumption by poor households. Households with irrigated land cultivated wheat and alfalfa. Chickpeas were also cultivated and used as fodder for goats. Farmers cultivated chickpeas in plots that have some residual humidity and often shortly after they noticed that their first crop (e.g. maize) would not give a good harvest when rains were delayed, which shows how farmers manage risk. Another risk management strategy was to cultivate sorghum rather than maize, because sorghum was

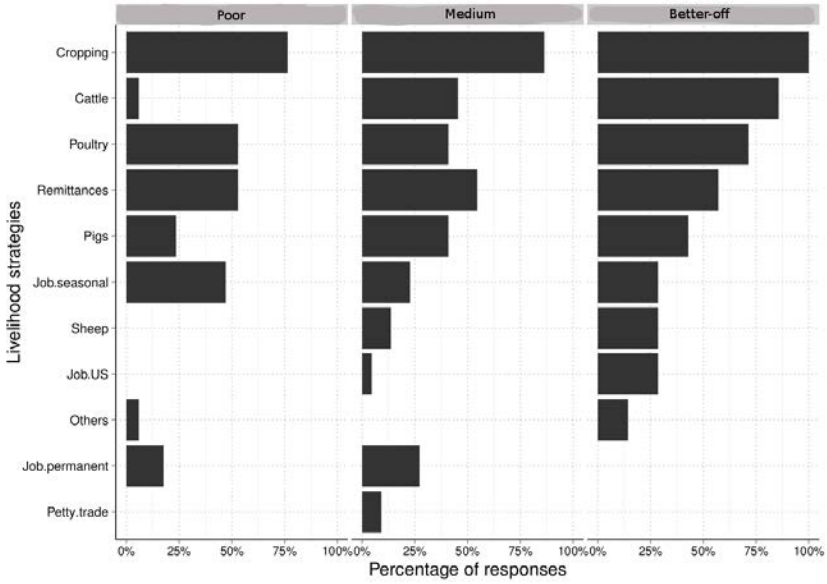

Figure 2.2: Households' strategies portfolio (n = 46)

perceived by farmers as more drought resistant than maize. Middle and better-off farmers cropped more land than they owned because they hired or borrowed crop land. In contrast, poor households could not always crop their own plots, because of lack of cash to get inputs or because of lack of male labour in the household. Among households from lower and medium strata keeping one or two sows to sell piglets was common, especially in the village Los Charcos. Cattle keeping was negligible for households in the lower strata compared to households in the medium and in the better-off groups. Better-off households keeping cattle owned relatively large cattle herds of about 100 head, whereas the few poor households with cattle had only one or two animals. Households income was often complemented with remittances from the US, agricultural wages and non-agricultural salaries from the nearby towns (i.e. Zamora and Tanhuato). Farmers reported that remittances were used to get inputs for the flock such as feed. Women were engaged in specific income-generating activities. Women from the medium group were selling chicken parts and cheese making. Making prayer beads and other religious crafts by sewing was common among women from poor households. Women in the poor or medium group were also engaged in seasonal work, such as harvesting vegetables and fruits, and in permanent jobs, such as packing strawberries for the frozen fruit industry of Zamora.

GOAT HUSBANDRY: PASTORALISM

In general, goat husbandry in the Bajío region can be characterized as a pastoral activity. Farmers were knowledgeable about the grazing behaviour of goats and their adaptation to the environment. Goats were herded to graze crops, crop residues and native vegetation

in communal land and roadsides. Figure 2.3 shows the results of a mapping exercise with farmers and shows how land resources were used in three villages. Farmers herded their goats to graze native grasses, fodder trees and shrubs in the hills of communal land and roadsides during the rainy season (July-October). The dry season lasts from mid October to mid June. In the dry season goats were herded to graze crop residues of rainfed crop maize, sorghum, chickpeas and irrigated crops of wheat. Farmers also herd their flocks to directly graze crops, mostly sorghum and chickpeas. Some other farmers kept their harvest to feed their goats in periods of poor forage availability. There were not many maize and sorghum residues left by the end of March. At this time of the year most farmers stopped with the grazing system and changed to stall- feeding, based on stored crop residues, crops and purchased forage and concentrates. Some farmers continued with grazing throughout the dry season and brought their goats to the communal land to browse shrub pods (*Huizaches*), chickpeas and wheat residues. All farmers, however, had to supplement their goats' feed with concentrates or crop residues.

Figure 2.4 shows a panoramic view of the valley during the rainy season. From the interviews we learned that the access to natural capital land was becoming difficult. The land counter-reforms of 1992 that established individual property over *ejido* land had an effect on the way villagers organized cropping and livestock husbandry. The first problem derived from this change was that there were less crop residues available for goats. Formerly, after the harvest, all crop residues were left for all village livestock to graze freely. "Now everything has an owner" (farmer, San José de Vargas). Hence, crop residues had a price. Payments in kind (goat kids) were common to access crop residues of neighbours. Farmers might let their goats graze neighbours' crop residues without asking permission. Goat farmers themselves recognised that they had some stigma for 'stealing' crop residues. Furthermore, the land counter-reforms of 1992 allowed external users to lease and purchase land. For example, in San José de Vargas, there was a mine in operation, which occupied a large portion of the communal land. In the vicinity of Los Charcos a feedlot for up to 10,000 cattle was established. Los Charcos farmers were concerned about the water reservoirs as the feedlot uses water for the animals and also for slaughtering and meat packing. Added to this, the feedlot sewage was discharged in the village canal, and the farmers were very annoyed by pestilent clouds of dust that covered their village since the feedlot started to operate.

DAIRY GOAT FARMING: MARKET AND MARGINS

Goats are an important financial capital. Flocks were mostly crossbred goats of dairy breeds, such as Saanen, French Alpine and Toggenburg. The longitudinal survey showed that annual milk yields per head averaged 422 litres (Standard deviation (SD) 106). Lactation started in mid October and the peak of the production was around mid April to the end of May. Milk yields dropped in July and August, and goats were dried off in September and October. Milk was sold at farm gate to the *cajeta* industry. Male goat kids were also sold. They fetch prices of around 270 Mexican pesos (MX$)[6]. Goat kid meat had a seasonal market at the end of the year (Christmas and New Years celebrations) coinciding also with the return of migrants. The role of goat husbandry as a source of income is shown in Figure 2.5. Plot A shows the importance of goat milk sales to the total on-farm gross margins (i.e. cropping and goat husbandry). Lower gross-margins were obtained by households with small flocks,

6 Exchange rate: 12.3 MX$ equaled 1 US$ in 2008 and 2009. Source: Banxico (2008)

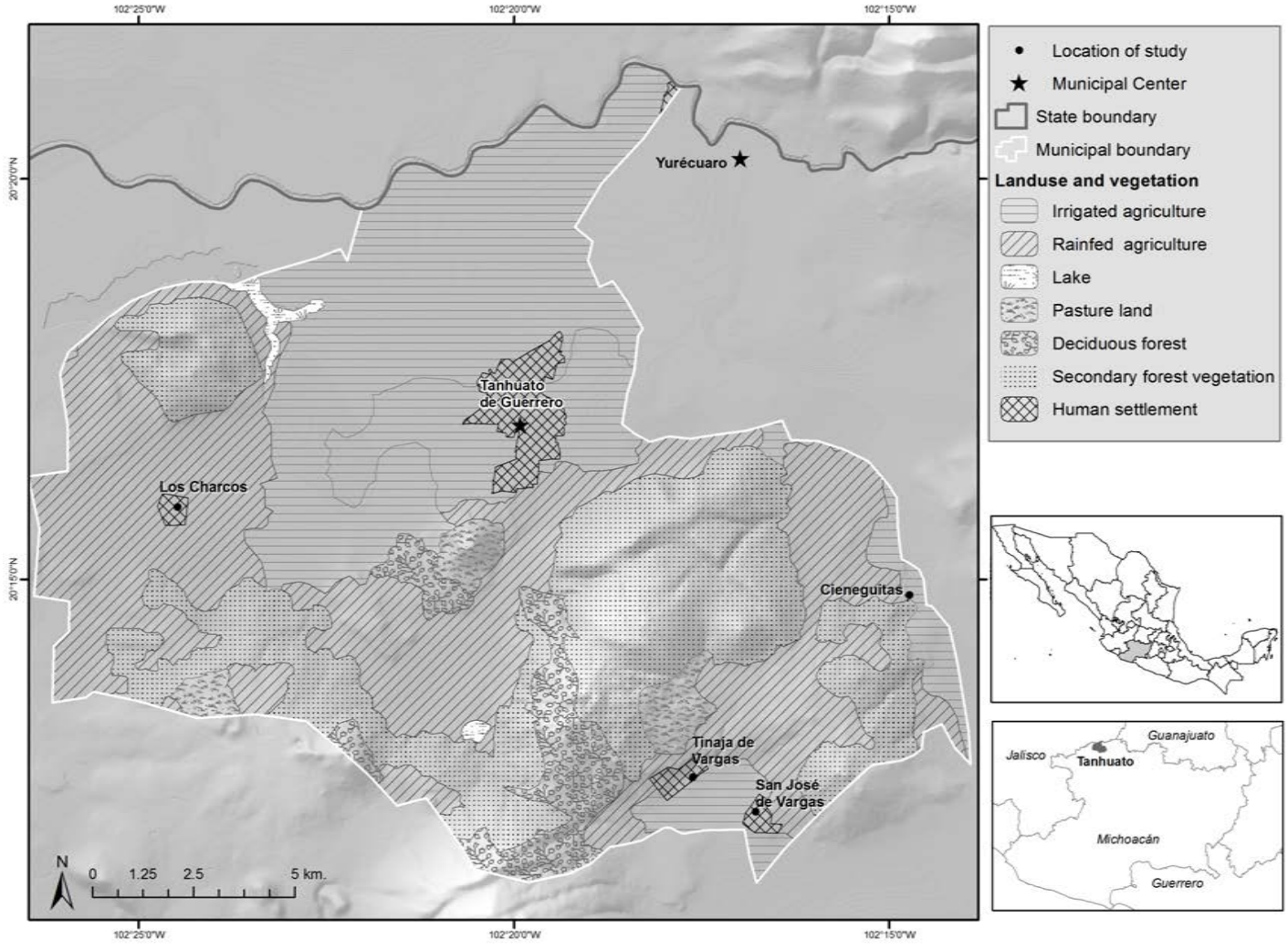

Figure 2.3: Natural capital: grazing areas in villages of Tinaja de Vargas, San José de Vargas and Los Charcos

Figure 2.4: Grazing goats in shrub land. Herding to hills occurs during the rainy season in the study region: white patches in the background are greenhouses

which belonged to the poor. There was a linear relationship between milk sales and gross margins. Plot B shows that cropping had a lower direct impact on on-farm gross-margins than goats. To some extent goat husbandry had a higher impact on gross margins when compared to cropping (plots A and B) because farmers used their own crops as feed, inputs for cropping were costly, and crops failed due to droughts.

Households in the medium and better-off strata obtained larger gross margins when compared to the poor, as shown in Figure 2.6 (plot A and B). The contribution of goat husbandry and cropping in relation to the poverty line is shown in Plot B. The gross margins per capita of poor farmers (median = 4,987, IQ = 3,895 - 11,948) and medium farmers (median = 9,029, IQ = 7,736 - 11,723) were under the poverty line. Only a better-off farmer was well above the poverty line.

The positive gross margins from goat husbandry were a reason for its popularity. For example, in one of the villages (Cieneguitas) where there were formerly three to four goat farmers, there were now 28 households with goat flocks, averaging 40 head (SD 36), according to a census done by an NGO. "[T]here are a lot of goats now, the truck used to come for 600 litres, now two trucks leave full of milk .. now everybody has 10-20 goats" (farmer, Cieneguitas). Another farmer comparing cattle with goats said that "cows do not produce, it takes two years before you can sell a calf" (farmer, San José de Vargas).

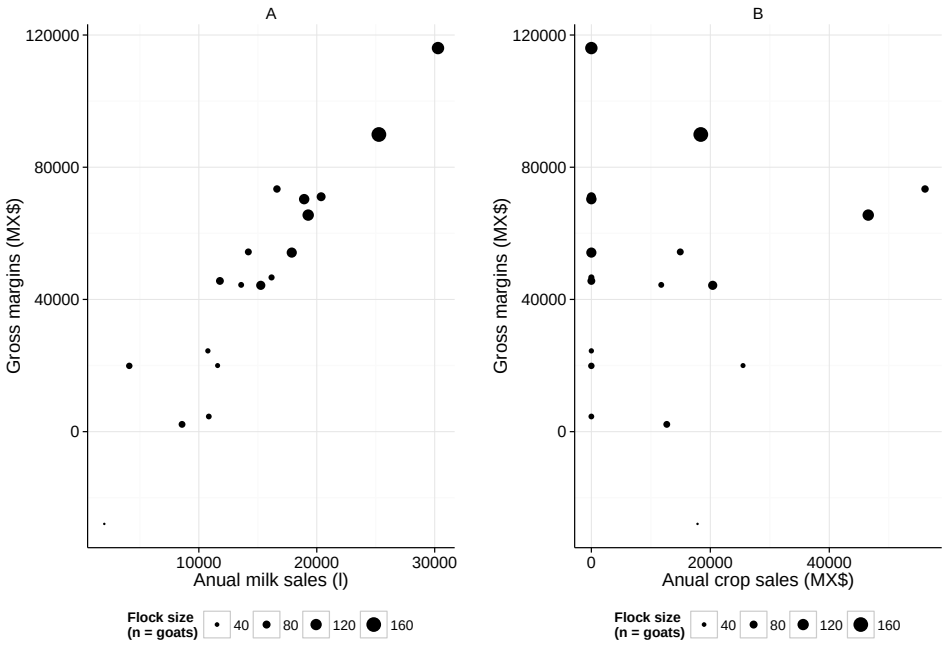

Figure 2.5: On-farm gross margins per year with regard to flock sizes. Plot A, on-farm gross margins according to annual farm milk production and flock size. Plot B, on-farm gross margins according to crop sales and flock size (n = 18)

Farmers main concern was the milk price though, they received $MX 4 (US$ 0.33) per litre and they felt that the price did not increase at the same rate as input costs (Figure 2.7). The *cajeta* companies justified their farm gate milk price because farmers produced little milk and milk quality was low. The managers of the *cajeta* plants claimed that "they [farmers] produced very little [individually], to fetch the milk at farm gate is very costly... they have very very inefficient systems, they keep many non-productive goats " (managers of the *cajeta* plants). The leading company in collecting the milk was a multinational company *Coronado*. There were two other prominent milk companies –*Cajeta Cabadas* and *Real the Potosí*. Figure 2.8, plot A shows the annual litres of goat milk processed by the *Coronado* plant in the region being over 12 million litres in 2010. There was a 38 percent increase in milk processed in 2010 compared to 2008. Plot B shows the seasonal variation of milk processing by this company. Such seasonal variation is directly related to the seasonal milk production of goats. Milk production peak was reached in spring time.

The *cajeta* industry controlled the goat milk market. The managers of *cajeta* local plants were known as the *'patrón'* (the boss) by farmers. To prevent the farmers teaming up to de-

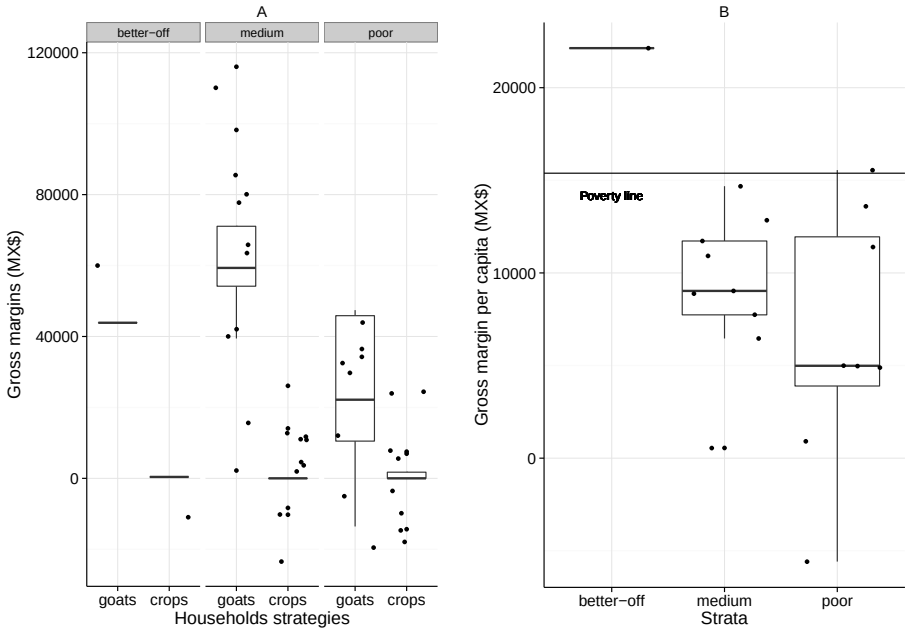

Figure 2.6: Gross margins from goat husbandry and cropping. Plot A, box whiskers plots of gross margins per activity, dots are the observations. Plot B, box whiskers plots of gross margins per capita in relation to the poverty line (n = 18)

mand a higher milk price, the industry paid a slightly higher price to farmers with larger flocks than to the majority of the farmers, which was a kind of *divide et impera* strategy. Adding water to milk was sometimes how farmers took revenge for the low price for their milk. They however, risked paying a penalty because random samples were taken to detect diluted milk. There were also patronage strategies used by the industry to ensure that a farmer's milk production was sold to them. When goats were dry, farmers asked for credits from milk traders and the industry. In turn, farmers sold their milk to their credit providers. Credits were given without interest rates and were paid back gradually when the milk production was peaking again. Usually these credits were used for daily living expenses and were equivalent to one or two weeks of a household's milk production. If credits were not given to farmers the industry risked losing their milk supply, because farmers then sold their milk to a competitor.

Selling milk to the industry at relatively low prices was not the only stressor for farmers. Brucellosis, a zoonotic disease (that can be transmitted from goats to humans), was endemic in the region (NGO personnel, personal communication). Milk processing to produce *cajeta* eliminates the risk of brucellosis for the consumers. The industry interviewees reported that

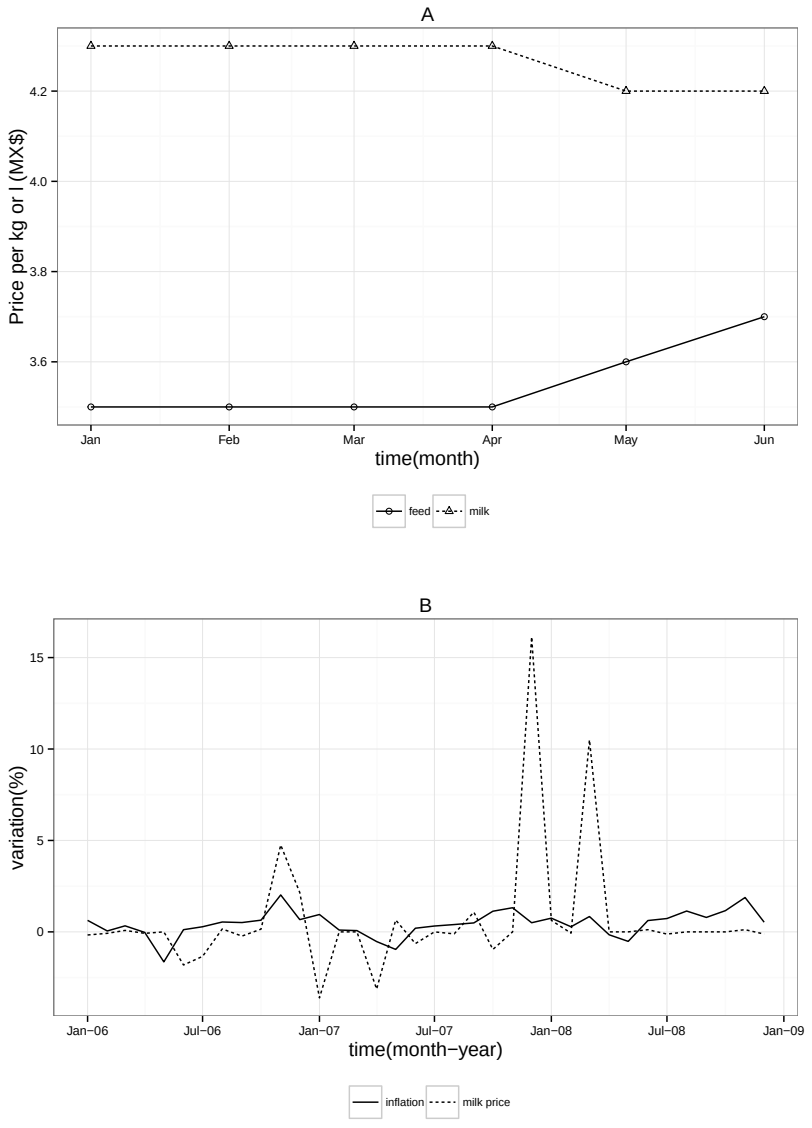

Figure 2.7: Goat milk price variation. Plot A, milk and feed (concentrates) prices per litre and kilo respectively, plot B monthly inflation in Mexico and variation of milk price

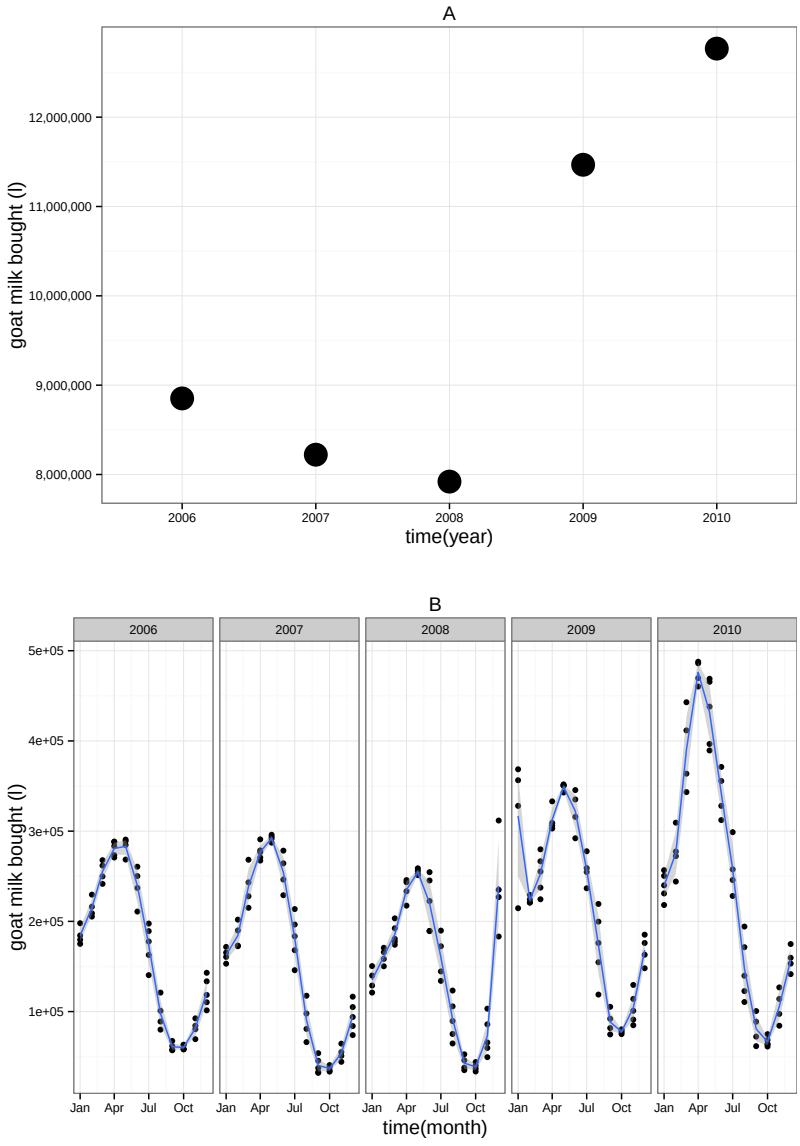

Figure 2.8: Milk processed by one of the *Coronado* plants in the region. Plot A, annual litres of milk processed from 2006 to 2010. Plot B, monthly variation of milk processed by the plant *Coronado* Jamay, Jalisco

there were no plans to pay premium prices for milk from brucellosis free flocks. In 56% of the households surveyed, respondents reported having at least one family member who had contracted brucellosis. Therefore, as a preventive measure, households avoided goat milk consumption. Farmers reported that physicians recommend staying away from dairy goat products as it is a cause of 'fever'.

LABOUR AND KNOWLEDGE

Goat husbandry involved only family labour and was done by men. They took decisions and received the cash from sales of milk. Women took the lead if their husband was ill, or when their husband migrated to the US. Invariably men were the herders and herding lasted for about six to eight hours. If husbands were absent due to migration, male children (some just over 10 years old) could take over the main goat husbandry tasks such as herding. Milking was done by hand once a day in the morning. Women swept the pens after the men left for herding. Usually one farmer alone was able to milk a flock of up to 70 head. For larger flocks other family members came to help, such as the *chivero* wife (Figure 2.9). Women also helped in washing milk containers and preparing menfolk's lunch for herding. In extended households women and young children help in other activities like herding and giving medical treatments. Table 2.2 shows neighbours' opinions about goat husbandry.

Figure 2.9: Woman milking a goat flock. Hand milking is predominant even when flocks are large. Tinaja de Vargas, Michoacán

Neighbours liked goat meat over goat dairy products. Goat farmers were seen as *gente de trabajo* (working people) by their neighbours, which was a compliment. In general farmers

had a relatively high esteem among their neighbours. For some farmers goat husbandry was an apprenticeship for their children. In the villages the highest school education available was secondary education. Therefore, goat husbandry was attractive for children who could not attend school beyond primary school.

Table 2.2: The opinions of farmers' neighbours about goat husbandry (n = 145)

	Villages			
	Cieneguitas	Los Charcos	San José de Vargas	Tinaja de Vargas
Number of respondents (n)	37	59	27	22
Low esteem to goat farmers (%)				
Destructive	3	4	15	0
Odour	0	15	4	0
High and neutral esteem to goat farmers (%)				
Working people	16	17	11	14
Generate employment	3	9	18	45
Good but no specific reason	8	2	4	0
Neutral	70	53	48	41
Dislikes about goats (%)				
Nothing	68	37	56	77
Smell	27	43	22	23
Smell combined with flies	5	20	22	0
Likes about goats (%)				
Nothing	11	13	19	14
Dairy product	5	5	0	5
Meat	84	70	74	73
Meat and dairy	0	12	7	9

During the transects we observed that farmers were skilful in various aspects of goat husbandry such as herding and curing diseases. For herding farmers used different calls to herd their flocks such as a call to urge the flock to come back, one to move on or a call to scare a coyote. Farmers trained also village dog pups to become herder dogs to protect flocks against thieves and coyotes. They predicted how long crop residues could last for their flocks and related the quality of crop residues with milk yields and were very familiar with the properties of the local vegetation (e.g. toxicity and nutritional value). Their knowledge of

the local ecology was also key. So, they planned routes to herd their flocks to the best spots for feed. Farmers used natural and local remedies to heal udder cuts and resolve placenta retention. They were also familiar in how to use modern drugs for deworming, vaccinating and curing other infections. They even knew how to treat acidosis in goat kids, a syndrome known locally as 'borrachito' (drunk syndrome in goat kids), with oral salts for hydration for human use. But farmers had the perception that their knowledge was not valued by outsiders. Farmers reported that an employee of the agricultural secretariat referred to them as ignorant and stinky.

ACCESS CAPITALS MEDIATED BY INSTITUTIONS

There was one NGO 'Subcomité de Productores de Ovicaprinos del Estado de Michoacán' (SPOEM) working with goat farmers. An exceptional situation with regard to supporting institutions for goat farmers. SPOEM was not initiated nor borne within the villages but in the capital of the state by an agronomist who envisaged the potential of smallholder farming systems and who intended to go in business with the most prominent goat farmers. The ultimate goal was to produce yoghurt (NGO personnel, personal communication). The entry point to start working with farmers was brucellosis control. The NGO was the channel through which governmental financial support for brucellosis control was given to goat farmers. The activities for brucellosis control included vaccination and testing to detect seropositive goats.

The ambitious brucellosis control programme (free for farmers) seemed to awaken interest from farmers to start goat husbandry and make groups. In some villages the more prominent farmers were encouraged to form a group of 10 to 20 farmers and start a extension group GGAVATT ('Grupos Ganaderos de Validación y Transferencia de la Tecnología')[7]. Farmers in these groups requested credit to acquire physical capital (e.g. pens).

We were informed that 48 farmers had received credit. We noticed that credit reached the medium and better-off farmers. The project better known as the *tejabanes project* (the pens project) was a kind of 'one size fits all' package of a pen and a milking machine per farmer, a cooling tank per group and also pasteurizers for some farmers. However, many things went wrong. First, pens were stall-fed prototypes, although forage grazing was the main management system. Second, farmers reported that pens were constructed with cheap low-quality materials, differing to the specifications in the original credit plan. One farmer reported having lost some goats when they got trapped and died within the post of the feeding fences, due to the bad design. Doors and fences of the pens were falling apart at the time of the field work. In addition, some better-off farmers already had a good size pen so they ended up having two pens. As a result, some of these pens were later used for other purposes. Figure 2.10 shows a 'modern' pen acquired through this project which was used to keep fighting cocks instead of goats, while some other farmers used the pens as storage for feed. Other equipment given was obsolete too. The milking machines were rarely used because they ran on petrol or electricity, so they required an extra input. "We are not paid more for using it so it is not worth it" (farmer, Las Fuentes). The small ramp to milk goats served instead as a bench and table to have lunch, and was not used to milk goats. The cooling tank was placed where there was no electricity (i.e. in Tinaja de Vargas). Farmers launched a formal accusation of corruption for the poor quality of the pens and some farmers stopped paying the credit. In response, the government ceased the financial

7 Livestock farmers groups for technology validation and transfer

Figure 2.10: A 'modern' goat pen used to keep fighting cocks, Michoacán, Mexico

support for the brucellosis campaign when these issues were brought up. Apparently it was a revenge against the NGO for supporting farmers to complain about governmental corruption. Finally, some farmers who started an extension group GGAVATT complained about not receiving any financial support as the neighbour village groups did. Interviewed farmers reported that they had invested time and money in this group and nothing came out of it. In summary, the pens project in Michoacán brought only problems, as one farmer reported.

2.6 DISCUSSION

Goat husbandry is part of the portfolio of smallholders' activities. Diversification has also been described in small-scale goat husbandry in northern parts of the country (Mora-Ledesma, 2011). The increasing number of households involved in goat keeping in various villages indicates that there is a growing interest among smallholders in goat keeping. Goat milk has become an important commercial commodity, crops are mainly used for home consumption and used as feed for the goats. Commercial cropping has become a risky activity for smallholders, whereas goat husbandry is relatively more feasible especially for those having little

or no land. As sale of milk gives a regular income, farmers try to optimize their income sources and manage risks through goat husbandry. This shows also farmers agency; even among the poor, taking an active role to make their living a sustainable livelihood as they pursue autonomy and self-sufficiency. Goat husbandry seems to support those who argue that smallholders are not to disappear, the so called *campesinistas* (peasantists) (Kay, 2008).

We showed that smallholders have a rich knowledge of keeping goats; very different to how industry managers and bureaucrats portray a *chivero*. Mastering a pastoral system in a relatively harsh environment is something to be recognised (Krätli and Schareika, 2010). This type of knowledge is described elsewhere in Africa (Oba, 2012) and in other parts of Mexico (Mora-Ledesma, 2011). There is a rich goat husbandry knowledge transmitted through generations; part of this traditional knowledge originated during the Spanish colonial period around 500 years ago. The smallholder farming systems have subsisted all these years and are quite efficient given the small size cropland properties. Smallholders make use of abundantly available natural capital, the so-called 'unproductive' shrub land.

Social capital is a key factor in goat husbandry, represented as community companionship, trust and the work of family members to support various tasks of keeping a flock. A main drawback for smallholder goat husbandry was a weak community social capital due to violent events. Violence is increasing in the whole country, and in Michoacán it is especially disturbing as murders were 100% higher in 2009 than in 2006 (INEGI, 2014a). Although the analysis of this violent environment goes beyond the scope of this paper, it constitutes an example of the consequences of the destruction of livelihoods in Mexico's rural villages. As we were informed, farmers flee and stop farming to avoid violence in one of the villages.

Our aim was also to understand the role of goats in improving poor people's livelihoods. This was done by investigating the role of goat husbandry among three groups of farmers defined as 'poor', 'medium' and 'better-off'. Farmers said that in general having goats was better than not having goats. For poor households goat husbandry was more vital than for the medium and better-off. The last two groups had a wider range of activities than the poor group. However, the role of goat husbandry to overcome the poverty line (i.e. fulfill basic necessities) is far from ideal. Most households were not earning enough per capita to overcome the poverty line of MX$ 15,348 per year (the equivalent of $\sim$ US$ 1,250). Flock size is factor in the overall on-farm gross margins (i.e. crops and goats). Poor farmers would need to own at least 30 adult dairy goats per capita to move to the medium group.

We did meet also extended households (two) that managed to keep relatively large flocks $\geq$ 400 goats (33 goats per capita), which allow them to acquire land. There were at least three key capitals for these extended families in their process to consolidate their capitals. First, there was a good individual goat social capital (i.e. family cooperation), second, human capital (i.e. labour of two or three generations including women and children) and natural capital (i.e. shrub land, and village crop land residues). However, we met cases of young couples in the poor category with relatively small flocks (approximately 15) where men were eager to migrate to the US. Therefore, claiming that goats can let people step out of poverty is not that straightforward as it is read in literature (Peacock, 2005; de Vries, 2008). Farmers in middle and better-off groups cultivated more land and of higher crop potential. Therefore they have more feed for their flocks. The poor have to restrain their flock size because they lack their own feed sources and have to buy extra feed. Poor households owned small plots (1 to 2.5 ha) and due to lack of financial resources and male labour due to US migration,

they could not cultivate their plots. Farmers with little crop land can have however, access to crop residues of neighbours and communal grazing land to feed their flocks. But, the land counter-reforms of 1992 threatens the access to these resources.

The neoliberal administrations tend to favour large farm operations (e.g. feedlot) and mining. This is leading to exploitation of vast land areas and its resources by powerful companies. The potential of new conflicts due to delimiting access and competition for resources is just around the corner as it occurs elsewhere (Hollander, 2013). An example in Mexico is the experience with mines: local communities do not get what they are promised, mines restrict access to communal grazing land and pollute air, soil and water (Rodríguez Wallenius, 2011). Similarly, the feedlot enterprise in the vicinity of one of the villages pollutes air and water sources.

Goat milk is a commodity that generates a regular income flow for households, however the milk trade is disadvantageous for farmers. A similar disadvantageous dairy marketing has been described in northern parts of the country (Gómez-Ruiz et al., 2012). There was a huge contrast between the farmers' uneasy economic situation and the prosperous *cajeta* industry. Coronado is a subsidiary of *Bimbo*, worldwide the fourth largest food company and the largest bread manufacturer (Ochoa, 2013). Bimbo reported 20% larger profits in 2005 than in 2004 [8]. Farmers were paid about 13% of shelf price[9]. The caramel industry is the main winner here and as such it can be called 'food empire' (van der Ploeg, 2010), which sets its rules such as milk price and quality standards, e.g. checking watered milk, that are important for *cajeta* production.

Farmers' main concern is the milk price which is stagnant in relation to the inflation and to the prices of their inputs. The goat milk market is in a vicious cycle where milk price is low and therefore, the milk hygiene quality is low. Brucellosis, a zoonosis endemic in goat flocks of the region (Oseguera Montiel et al., 2013), does not receive enough attention. This is not an issue in the eyes of the *cajeta* industry. Given the current circumstances, the risk of getting brucellosis is carried only by farmers' families. This is detrimental to farmers' livelihoods because affected individuals are not able to work and may develop permanent disabilities e.g. arthritis, spondylitis (Corbel, 2006). Furthermore, brucellosis in goats is responsible for losses due to abortion and hence milk production is reduced (Corbel, 2006).

Controlling brucellosis could be an opportunity for farmers to find a niche market for a high quality dairy product. Currently such a market is exploited by a relatively small group of goat farmers $\sim$ 20 from the neighbour state Guanajuato. Farmers might need to team up to achieve a better market. Stories of smallholder crop farmers forming cooperatives can be found elsewhere (King et al., 2012). A cooperative lead by women may be a way to empower women. Women are mostly involved in milking and cleaning corrals, but they could be playing a key role when goat milk is further processed (e.g., cheese making). Poorer households should be included in such plans too. Farmers social capital such as cooperation and trust can be a starting point for developing cooperatives with the help of NGOs or governmental institutions. Unfortunately, good institutional support is lacking. Credit given to acquire

8 EMBITDA (earnings before interest, taxes, depreciation, and amortization) were MX$ 7,191 million (Bimbo, 2005)

9 A jar of 660g of *cajeta* Coronado was MX$61 (PROFECO, 2012). *Cajeta* main inputs are milk and sugar, for 660g of *cajeta* about 2 litres of milk and 660g of sugar are needed (Employee, personal communication).

'modern' equipment in a 'one size fits all' package indicates governmental institutions desire of a modern agriculture sector. However, there was a mismatch between the package designed and the extensive grazing system used by the majority of goat farmers. A programme aiming to improve the pens of all farmers (not only the 'better-off') would have had a higher impact than the *Proyecto de los tejabanes*. The project only reached a really small fraction of the goat farmers of the region. In the whole state there are 11,281 goat farmers INEGI (2007).

2.7 CONCLUSIONS

Goat husbandry in the Bajío, Mexico, is embedded in a complex context influenced by neoliberal policies that do not favour the small-scale farming sector. However, goat husbandry has a growing interest among farmers, partly because cropping has become risky and less profitable. Farmers see in goats a source of income, security, credit, prestige, independence, food, manure and apprenticeship for young children. The interest is present among all socioeconomic strata. For the poor, goat husbandry was one of the main livelihoods strategies. Whereas better-off and medium group households had a wider range of activities. Wealthier farmers had relatively larger flocks and higher gross margins from goat husbandry than poor households. There were households who strengthened other capitals and strategies through goat husbandry. But these are just a handful of stories. The potential of goat husbandry as a tool for poverty alleviation is not visible yet. A dairy market oligopoly is a main drawback. This is partly linked to brucellosis in flocks, because the industry does not pay for high quality milk – hence there is no interest in tackling the brucellosis problem. Farmers are powerless against the dairy industry. There are opportunities for a better dairy market if brucellosis could be eradicated from the flocks. This could also reduce the risk of brucellosis in humans. Natural capital (i.e. communal grazing land) is key in goat husbandry. Historically goat husbandry has persisted because of the abundance of this 'unproductive' land. Powerful external users have interest in this land and therefore are a threat for smallholder goat husbandry. Given the relatively low amount of crop land available for each household we showed that small-scale goat husbandry is productive, in contrast to the dominant discourse that smallholder systems are 'unproductive'.

3

PREVALENCE AND RISK FACTORS FOR BRUCELLOSIS IN GOATS IN AREAS OF MEXICO WITH AND WITHOUT BRUCELLOSIS CONTROL CAMPAIGN

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Tropical Animal Health and Production, 2013, 45:1383–1389

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ABSTRACT

Brucellosis is a major constraint for small-scale goat farming systems in Mexico. This study estimated the prevalence of testing positive to brucellosis and identified and quantified risk factors in goats from small-scale farms of Michoacán that had participated in a brucellosis campaign (i.e. vaccination, serological testing, culling and awareness) and of Jalisco that had negligible brucellosis campaign participation. A cross-sectional serological survey was conducted among 1,713 goats of 83 flocks. The prevalence of testing positive to brucellosis was higher (38 %) in Jalisco than in Michoacán (11 %). Logistic regression analysis indicated that goats from Michoacán had lower odds to test positive for brucellosis (odds ratio (OR)=0.32, 95% confidence interval (CI) 0.21 — 0.48) compared to goats from Jalisco. Goats in zero-grazing systems had lower odds than goats in grazing systems (OR=0.22, 95% CI 0.09 -– 0.57). When goats were kept in pens with low density (0.002 to 0.22 goat/m^2), odds was lower (OR=0.44, 95% CI 0.28 -– 0.67) compared to goats kept in pens with higher density (0.23 to 1 goat/m2). Odds was higher for testing positive when farmers bought goats from goat traders (OR=1.82, 95 % CI 1.15 -– 2.87) compared to farmers who did not. If scavenger poultry had access to goat pens, the odds was half (OR=0.52, 95% CI 0.33 -– 0.83) of those where poultry had no access. Regular disinfection of the pen reduced the odds (OR=0.66, 95 % CI 0.44 — 0.99) compared to where disinfection was not regular. The brucellosis control campaign was effective in reducing brucellosis seropositivity.

Keywords: Brucellosis, Control, Mexico, Small-scale goat farming, Vaccination

3.1 INTRODUCTION

Goats are an important source of food for smallholders in Mexico and surely of other relevant, but less studied, functions such as employment, income, insurance, identity and prestige. Often goat husbandry is carried out in extensive grazing systems and with low external inputs (Rebollar Rebollar et al., 2007; Hernández et al., 2011). For example, in most goat flocks (88%) vaccination, deworming, feeding concentrates and technical assistance are not implemented (INEGI 2007). In Mexico, small-scale goat farmers are known as *chiveros*, they employ mostly family labour and their flocks can average 20 to 70 head (Vargas López, 2003; Hernández et al., 2011).

Brucellosis in goats, caused mostly by the bacterium *Brucella melitensis*, constrains development of small-scale goat farming. It causes abortion, mastitis, infertility and goat kid mortality (Blasco, 2010), and thus causes losses for the livelihoods of goat keeping households. *B. melitensis* is also among the agents that accounts for most cases of human brucellosis and might be considered the most virulent (Doganay and Aygen, 2003; Franco et al., 2007). Although the brucellosis level in the Mexican human population (112 M) is low (in 2008 about 2,000 people tested positive to brucellosis (DGE, 2008)), the incidence of brucellosis is most probably much higher as brucellosis surveillance is passive. Brucellosis control in goats started in 1971, but it is still endemic in Mexico. An estimate of brucellosis prevalence for the whole Mexican goat population is not available. But in some regions prevalence values ranging from 6 to 10% have been reported (Solorio-Rivera et al., 2007; Acosta-González et al., 2009; Sánchez et al., 2009). Mexican legislation regarding caprine brucellosis control is based on vaccination with *B. melitensis* Rev 1, serological testing and culling of seropositive goats (SAGARPA, 1996), but it is not applied evenly across the country and its impact is not well known.

The objective of this study was to determine the prevalence of brucellosis and to identify and quantify risk factors for testing positive to brucellosis in goats from small-scale farming systems in two areas: one where there was an on-going brucellosis campaign (i.e. vaccination under Mexican field conditions, testing, and awareness) from 2002 until 2007 and one where the brucellosis campaign was negligible among small-scale goat farms.

3.2 MATERIALS AND METHODS

STUDY REGION AND STUDY POPULATION

The study region was located in two neighbouring states: Michoacán and Jalisco. In Michoacán, an intensive vaccination programme using B. melitensis Rev 1, serological testing and awareness had been carried out. Whole-flock vaccination was conducted using a reduced dose of B. melitensis Rev 1 (4×10^6) from 2002 to 2005. From 2006 to 2007, only young goats (age ≤ 4 months old) were vaccinated (subcutaneously) with a standard dose of *B. melitensis* Rev 1 (6×10^{10}). Serological testing with Rose Bengale test (RBT) and complement fixation test (CFT) was done in the early stages of the campaign. In contrast, in villages of Jalisco, the brucellosis campaign was negligible; most goat flocks had never been vaccinated or sampled for brucellosis testing.

We used the 'snowball' technique (Biernacki and Waldorf, 1981) to recruit goat flocks. First, we identified rural villages with goat flocks and once villages were identified, farmers

were informed about the study through workshops or at an individual basis. In total, we recruited 28 flocks from Jalisco villages: Labor Vieja (20° 4315 N 102° 6497 W), Barranca el Aguacate (20°4475 N 102°5837 W), and Canales (20°4067 N 102°6169 W); and 55 flocks from Michoacán villages: San José de Vargas (20°2000 N 102° 2792 W), Tinaja de Vargas (20°2104 N 102°2935 W), Los Charcos (20°2645 N 102°4081 W) and Puerta de Vargas (20° 1775 N 102°3012 W). Flocks which had been recently vaccinated ($<$ 12 months) with Rev 1 were excluded to avoid a postvaccinal reaction with the tests we used: RBT and CFT.

A small percentage of farmers (4 %) did not want to take part in the study; they believed that they were going to be forced to eliminate brucellosis-positive goats. The number of goats to be tested within each flock was calculated using Win Episcope (module disease detection) (Thrusfield et al., 2001). The probability of finding at least one positive goat was set at 0.95, and the number of positive goats in a flock was calculated with an expected prevalence of 10 %. Goats within flocks were sampled randomly. If the flock size was less than 22 goats, all goats had to be sampled for brucellosis detection. In total, 90 flocks were sampled; five of them were excluded because they were vaccinated within the 12-month threshold. Another two flocks were left out because the questionnaires were not complete. Thus, goats from 83 flocks were included in the analysis. Number of samples per flock taken ranged from two to 30; in 73 flocks, more than ten samples were taken. Goats were bled from their jugular vein (about 10 ml) using vacuum tubes. Blood samples were let to clot at 4°C for 12 to 72 h. Sera were harvested and kept at -20°C until laboratory analysis. Farmers were interviewed using a questionnaire about flock management (Table 3.1). The questionnaire was first tested for adequacy with three farmers.

LABORATORY ANALYSIS

Serum analysis was conducted at the laboratory of serology (ISO 9001:2000 certified) of the Faculty of Veterinary Medicine at the National Autonomous University of Mexico (UNAM). Samples were tested first with 3 % RBT. The RBT was done by the first author. For RBT, 30 μL of serum was mixed manually with a dental wooden stick with 30 μL antigen Aba Test Tarjeta 3 % on a clean transparent glass plate. The antigen used contained *Brucella abortus* strain 1119–3 which is Rose Bengal-stained and of acid-adjusted *pH* (3.6). Any agglutination observed within 4 min after mixing was deemed a positive test. Each bottle of antigen was tested with a panel of case and control samples, distilled water and a physiologic saline solution. Positive samples to RBT were tested with CFT warm fixation protocol (Nielsen and Yu, 2010) by specialists at UNAM.

STATISTICAL ANALYSIS

Statistical analysis was done in R (2014). For summary statistics, outlier detection and typing errors, we used R package 'Hmisc' and for graphics 'ggplot2' (Harrell and with contributions from many users, 2009; Wickham, 2009). In the analysis, the dependent variable had a binomial distribution: coded as 1 if the sample was positive to both RBT and CFT and otherwise coded as 0. Logistic regression with logit link was used to analyse the effect of explanatory factors on the odds of testing positive to brucellosis with R package 'gee' (Carey et al., 2011). Factors investigated included management, general household data, biosecurity, knowledge of brucellosis and goat characteristics (Table 3.1).

Table 3.1: Goat and flock level factors on which information was obtained through a questionnaire for 1768 goats from 84 flocks

Variables	Level
Household characteristics	
Farmer gender	male, female
Goat farming livelihood priority	yes, no
Farming experience	years
Head household years in school	>3, ≥ 6, <6
Flock size	head
Knowledge of brucellosis	score[a]
Flock origin[b]	Michoacán, Jalisco
Corral hygiene	
Use of disinfectants	yes, no
Brushing corrals	yes, no
Placentas and foetuses disposal	yes, no
Dog eats neighbour flocks placentas	yes, no
Biosecurity	
Brought in replacements	yes, no
RBT test for entering goats	yes, no
Domestic animals reach flocks pen (i.e. poultry,pigs, dogs, cattle)[c]	yes, no
Exchange goats with goat trader	yes, no
Lends or borrows bucks	yes, no
Close contact with neighbour flocks: through pen or fence sharing	yes, no
Management	
Pen section for parturient goats	yes, no
Goats density in pen	low and high[d]
Husbandry grazing system	zero-grazing, grazing
Goats characteristics	
Parturitions	number
Sex	male, female

[a] involved questions to farmers such as: if they knew that brucellosis is contagious among livestock, if it is zoonosis, symptoms in humans and clinical signs in livestock, route of transmission and that there is a campaign to control it.

[b] Michoacán flocks vaccinated and Jalisco flocks no vaccinated against brucellosis

[c] Analysed each domestic animal individually

[d] low (>0.22), high (<0.22) head per m^2

First, all factors were screened by univariable logistic analysis that included flock as random effect to adjust for dependency of goats within flocks (using exchangeable correlation structure). Variables with $p \leq 0.25$ were all in cluded in a multivariable model. The final model was constructed using a backward elimination procedure. The variable that showed the highest p value was removed, and the model was refitted in an iterative procedure until all variables were significant ($p \leq 0.05$) or were confounders. A variable was defined as confounder if its removal caused changes in regression coefficients of at least 25% or an absolute change of 0.1 if β was between -0.40 and 0.40. Two-way interactions of variables in the final model were evaluated. Fit of the final model was assessed by the le Cessie–van Houwelingen test statistic (Hosmer et al., 1997) in a model without the random effect using the R package 'Design' (Harrell, 2009).

3.3 RESULTS

SEROLOGICAL RESULTS

Prevalence of goats testing positive to RBT and CFT was 19% (23% for RBT only). In the vaccinated area, the prevalence was 11% and was much lower compared to the non-vaccinated area which had a prevalence of 38%. Figure 3.1 shows the distribution of flock prevalence[4] of testing positive to brucellosis. About 71% (59/83) of the flocks had at least one goat testing positive to brucellosis. Figure 3.2 shows the distribution of titres among flocks from the vaccinated area and the non-vaccinated area. The most frequent (51 %) titre was $\frac{1}{40}$, and flocks from the non-vaccinated area had a higher proportion of $\frac{1}{40}$ titres (64%).

STATISTICAL ANALYSIS

Fifteen variables had a p value ≤ 0.25 in the univariable logistic analysis (see Table 1) and were selected for the backward stepwise multivariable logistic regression procedure. Table 2 shows the odds ratio (OR) of seven predictors retained in the final model which was based on 1,671 goats from 81 flocks because some variables had missing values in two flocks. The odds of testing positive was lower for villages where there had been a brucellosis control campaign compared to that for villages where such a campaign was negligible (OR=0.32, 95 % confidence interval (CI) 0.21–0.48). Goats in zero-grazing systems showed decreased odds (OR 0.22, 95% CI 0.09–0.57) to test positive compared to goats in grazing systems. Lower goat density in corrals[5]. (0.002–0.22) of goats/square meter decreased twofold the probability that goats tested as brucellosis positive (OR 0.44, 95% CI 0.28–0.67) compared to goats kept in corrals with high density (0.23 to 1 goat/m^2). If farmers bought goats from goat traders, the odds of finding seropositive goats was higher (OR 1.82, 95% CI 1.15–2.87) compared to that of farmers that did not buy goats from goat traders. If poultry had access to goat pens, the odds for testing positive was lower compared to when poultry had no access to goats pens (OR 0.52, 95% CI 0.33–0.83). Finally, the odds of testing positive when farmers frequently disinfected their pen was lower compared to when farmers did not disinfect it (OR 0.66, 95%

4 Our sampling design was not intended to detect prevalence at flock level as such; therefore, we did not include smallest flocks (less than ten goats).

5 This is about the suggested space for does in pens with an area for exercise 4.5 m^2 (Gómez y González et al., 2009)

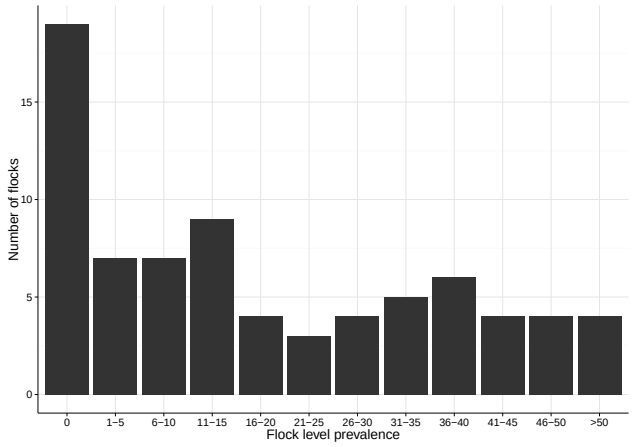

Figure 3.1: Prevalence of testing positive to brucellosis in goat flocks (flocks with less than 10 goats excluded)

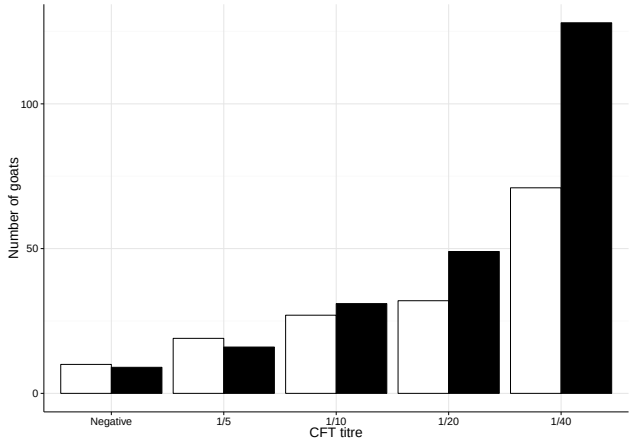

Figure 3.2: Complement fixation titres in goats from areas without (black bars) and with (white bars) brucellosis control campaign

CI 0.44-0.99). Although bringing goats into the flock recently was not significantly associated to testing positive, it was retained in the model because it was a confounding factor for buying goats from goat traders. Variables retained in the final model did not show any significant interaction. The percentage of unexplained variance accounted for by the random flock effect was small (7%). According to the le Cessie–van Houwelingen test result (p value of 0.5) for the goodness-of-fit test, the model fitted well the observations.

Table 3.2: Multivariable logistic analysis[a] of potential risk factors related to testing positive to brucellosis of 1671 goats from 81 flocks of Michoacán and Jalisco, Mexico[a]

Variable	Level	N	Prevalence	OR	95% CI	$p-value$
Flock origin (state)[b]	Jalisco	500	37.4	1.0	Ref	-
	Michoacán	1671	11.1	0.32	0.21 – 0.48	<0.001
Husbandry system	grazing	1460	21.1	1.0	Ref	-
	no grazing	211	4.3	0.22	0.09 – 0.57	<0.001
Goat density (head/m^2)	High (0.23: 1)	1042	23.2	1.0	Ref	-
	Low (0.002: 0.22)	629	11.9	0.44	0.28 – 0.67	0.001
Exchange goats with trader	No	816	13.7	1.0	Ref	-
	yes	855	23.9	1.82	1.15 – 2.87	0.02
Poultry reach the goat pen	No	397	27.9	1.0	Ref	-
	Yes	1274	16.1	0.52	0.33 – 0.83	0.01
Pen disinfected regularly	No	930	21.9	1	Ref	-
	Yes	741	15.2	0.66	0.44 - 0.99	0.04
Bringing in goats recently[c]	No	719	14.7	1	Ref	-
	Yes	952	22.1	0.69	0.43-1.09	0.1

[a] Percentage of total variance explained by flock equals 6.9%
[b] Michoacán (brucellosis control campaign) and Jalisco (non-brucellosis control campaign)
[c] Variable retained because it is a confounder

3.4 DISCUSSION

In this study, we determined the prevalence, and identified and quantified risk factors, of testing positive to *Brucella* infection in goats from small-scale goat farming systems in a region with and without participation in a brucellosis control campaign. The brucellosis control campaign in Michoacán was popular among farmers as vaccination and serological testing were free and culling was recommended, but there was no economic compensation from the government to cull goats that tested positive. Unfortunately, the campaign was discontinued in those villages since 2008 because the government withdrew the financial support to the NGO (Subcomité de Productores de Ovicaprinos del Estado de Michoacán) that had been involved in conducting the campaign.

We included samples of vaccinated goats if at least 12 months had elapsed between vaccination and sampling. We based this 12-month threshold on that of Alton (1987) who stated that serological testing with CFT is reliable if at least 12 months has elapsed between vaccination and testing using a standard dose of Rev 1. In addition, only CFT titres $\leq \frac{1}{10}$ were deemed positive as in Jones et al. (1973) because using a lower titre threshold such as $\frac{1}{1}$ postvaccinal reactions can last longer (Díaz-Aparicio et al., 1994).

The prevalence of testing positive to brucellosis was much higher in goats from the area where the brucellosis control campaign was negligible (38%) compared to that in goats where the brucellosis control campaign had been conducted for about 6 years (11%). Vaccination efficacy as a core measure for brucellosis control has been demonstrated elsewhere (Roth et al. 2003 and Zinsstag et al. 2005 for Mongolia; Minas et al. 2004 for Greece; Al-Majali 2005 for Jordan; Ward et al. 2012 for Tajikistan). Vaccination against brucellosis is highly rewarding because it reduces abortion rates in goats and the incidence of human brucellosis (Minas et al., 2004; Zinsstag et al., 2005). Besides vaccination, the lower prevalence of testing positive to brucellosis found in goats in the vaccinated area can also be attributed to serological sampling in various goat flocks during the brucellosis campaign, which may have given farmers the opportunity to cull or sell goats that tested positive. About 50% of the farmers from Michoacán indicated that they had sold goats that tested positive during the brucellosis control campaign.

Goats in grazing systems had higher risk of testing positive to brucellosis compared to goats in zero-grazing systems. Grazing is very popular among small-scale goat farmers, and the only possible way for many farmers to keep a flock because feeding is for free. Goats often graze on communal land where other goats and cattle graze too. Also, farmers combine four to five flocks to graze distant parcels and keep them at night in common pens. These contacts with other livestock increase the probability of *Brucella* spp. transmission. A brucellosis-susceptible goat kept in a higher-density environment has increased exposure to carriers of *Brucella* spp. such as from other goats and fomites within the pen. The lower risk of testing positive when goat density in pens was low was also found by Solorio-Rivera et al. (2007).

Buying goats from traders increased the risk of testing positive. Goat traders buy and sell goats from many different farmers and from different regions in an uncontrolled way from a sanitary point of view. No brucellosis testing is performed previous to transportation of traded goats. Current regulations oblige to test animals for brucellosis especially if they are to be transported from one state to another. And if a goat tests positive, the goat should

have a 'B' fire mark in one of its cheeks. But rarely any of these measures are implemented. Goat farmers are not committed to have a flock free of brucellosis as the current goat milk market does not provide any incentive for brucellosis-free milk production. Currently, goat milk is sold to the caramel industry; during caramel production, milk is processed at high temperature, making the risk of brucellosis for consumers nil. A brucellosis control and eradication programme needs to be linked to a high quality-dairy market; an example being goat farmers from a neighbouring state, Guanajuato, who produce soft cheese for a niche market in central cities of the country. Most importantly, farmers and other people handling goats and raw goat dairy products will be less at risk to get brucellosis if one is aware of the consequences of brucellosis in humans; such awareness will make farmers motivated to get and keep their flock brucellosis-free.

The odds of testing positive was lower if free-roaming poultry reached goat pens. Poultry removes (eats) infected material (e.g. placentas). If brucellosis-infected goats do abort or give birth, their placentas can contain large amounts of *Brucella* spp. (Enright, 1990). However, poultry can also act as mechanical vectors of brucellosis (Merck, 1986). Junaidu et al. (2006), for example, found a brucellosis prevalence of $\sim$3 % in poultry housed with ruminants, and therefore, they discourage 'common' housing of poultry and ruminants in Africa.

Finally, pen disinfection also reduced the odds of testing positive to brucellosis in goats. Often, farmers use hypochlorite and lime solutions to disinfect pens. The effect of the use of disinfectants found here is probably a combined effect with other sanitary practices (e.g. sweeping, removing placentas and others) that we did not find being associated to testing positive and might need further assessment.

3.5 CONCLUSIONS

Our results show that goats from an area where a brucellosis control campaign was conducted intensively had a lower risk of testing positive to brucellosis than goats from an area without a brucellosis control campaign. Risk to test positive was also lower if goats were kept at lower density, in zero-grazing systems, where pens were disinfected and where poultry had access to the pen. Also, goats belonging to farmers who buy goats from traders had higher risks of testing positive to brucellosis. Reducing goat density in pens, ensuring regular disinfection of the pen and ensuring that farmers get replacements from outside (e.g. goat traders) that test negative to brucellosis are factors that can contribute to control brucellosis transmission. As grazing is a very important feed source and essential for the economic sustainability of the production systems described here, a brucellosis control programme based mainly on vaccination should target all goats, but when resources are limited, vaccination should specifically aim at goats that graze.

4

FINANCIAL ANALYSIS OF BRUCELLOSIS CONTROL FOR SMALL SCALE GOAT FARMING IN THE BAJÍO REGION, MEXICO

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Submitted Preventive Veterinary Medicine

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ABSTRACT

Brucellosis is an endemic disease in small-scale goat husbandry systems in Mexico. It is a zoonosis and the economic consequences can be large, although estimates are not available for the Mexican goat sector. Our objective was to conduct a financial analysis of brucellosis control in a prominent dairy goat production area of the Bajío region, Mexico. We used three models: (1) a brucellosis transmission model at village flock level (n = 1000 head), (2) a flock growth model at smallholder flock level (n = 23 head) using output of model 1 and (3) cost-benefit analysis of several brucellosis control scenarios based on output of model 2. Scenarios consisted of test-and-cull or vaccination or a combination of both compared to the base situation (no control). The net present value (NPV) of using vaccination per goat was 3.2 Mexican Pesos (MX$) and the benefit/cost ratio was 3.8. The NPV for the goat population of the region was MX$ 123,078, (∼US$ 10,000) over five years. However, brucellosis prevalence was predicted to remain relatively high at about 12%. Control scenarios with test-and-cull predicted to reduce brucellosis prevalence to less than 3%, but this produced a negative NPV ranging from MX$ -676,407 to - 1,226,085. A brucellosis control campaign based on vaccination with full coverage is economically profitable for the goat dairy sector of the region. Smallholders would need financial support in case test-and-cull is applied to reduce the prevalence more quickly.

Keywords: animal health economics, *Brucella melitensis*, goat husbandry, goat dairy production, Latin America, smallholder, zoonoses transmission

4.1 INTRODUCTION

Caprine brucellosis is a ubiquitous disease caused by bacteria genus *Brucella spp* which may induce reduced fertility through abortion, stillbirths and orchitis in bucks (Corbel, 2006). *B. melitensis* transmitted by goats is also the most virulent and important cause of human brucellosis. Humans with brucellosis suffer from fever, chills, sweats, aches; complications involving cardiac, ostearticular and neurological systems have also been reported (Corbel, 2006). Diagnosis of human brucellosis is not straightforward because main symptoms are not specific. Therapy consists of at least 6 weeks of antibiotic treatment. Despite these severe consequences in both goats and humans, brucellosis in livestock is still uncontrolled in many countries of the global South (OIE, 2014). In the Bajío region of Mexico for example, where small-scale goat husbandry is common, the average seroprevalence of caprine brucellosis was estimated to be 20% (Oseguera Montiel et al., 2013).

The core of the brucellosis control and eradication campaign in Mexico consists of vaccination, and a test-and-cull strategy of seropositive animals. Mexican directives state that caprine brucellosis is a notifiable disease and its control and prevention are compulsory. Therefore, all goat farmers should take part in the campaign, and costs should be shared between the government and farmers (SAGARPA, 1996). Reality is different, however, because local governments' and farmers' efforts and participation in brucellosis control is variable between municipalities, states and villages, resulting in a heterogeneous brucellosis prevalence across the country and within regions, e.g. a prevalence of 38% was reported for the state of Jalisco while it was 12% in the neighboring state of Michoacán (Oseguera Montiel et al., 2013).

A possible reason for not fully implementing control measures could be the lack of knowledge on the costs. Pioneer studies of cost-benefit analysis of brucellosis control in cattle were done in the UK and in Spain (Hugh-Jones et al., 1976; Bernués et al., 1997). More recently Coelho et al. (2011) reported a cost-benefit analysis of brucellosis control in small ruminants in the North of Portugal. In Mexico economic analyses of brucellosis are available at farm level for intensive dairy cattle farms (Montaño et al., 2007), but not for the Mexican goat sector. Mexico has a relatively large diversity of agroecosystems resulting in different goat husbandry systems and population densities across the country. A regional approach of controlling and preventing brucellosis is needed because goats from several flocks are herded together and trading promotes *B. melitensis* transmission between goat populations from different jurisdictions. The aim of this paper is to investigate the costs and benefits of several brucellosis control strategies and therefore to understand whether brucellosis control is economically profitable for small-scale goat husbandry in a dairy goat area of the Bajío region, Mexico. The main question is whether or not control of brucellosis in goat farming systems in this area is economically profitable.

4.2 MATERIALS AND METHODS

STUDY SITE

The study site is a basin area around the Chapala lake and the Lerma river in central west Mexico, which is part of the Bajío region. The study area is shared by two administrative jurisdictions (states): Michoacán and Jalisco; goats are moved back and forth between the two states for trading and grazing. The region has valleys where crop production is important.

The altitude of the area ranges from 1500 to 2000 meters above sea level. Prominent activities are grain production, (e.g. sorghum, maize, wheat), agro-industry of tinned fruits and vegetables, pork, and caprine and bovine dairy production. Figure 4.1 shows municipalities of two states of the Bajío region where goat husbandry is relatively prominent.

Goat husbandry is mostly carried out by smallholders based on extensive grazing systems with small flocks (median = 19, interquartile range 6 - 54) [4]. Total goat milk production of these relatively small flocks is over 12 million litres per year[5]. This milk is key input for the production of *cajeta* a sweet similar in taste to English caramel, a commodity for the domestic and US export market.

BRUCELLOSIS TRANSMISSION MODEL

Brucellosis transmission within a large village flock (n = 1000) was simulated with a compartmental deterministic model for a five-year period. With this model five control scenarios coded as b, i, ii, iii and iv were evaluated. A village flock was chosen rather than an individual flock because the bulk of the goat farmers apply extensive grazing, where goats from different flocks often come into contact with each other in grazing areas. We assumed that flocks goat population was made of female goats because approximates the type of flocks in the region, made of female:male ratio 27:1 in Michoacán and 44:1 in Jalisco, and because it facilitates the assessment on flock fertility.

Scenario b is a baseline scenario, with brucellosis control measures; in i mass vaccination (whole flock) with a standard dose of Rev 1 ($1 - 2 \times 10^9$ colony-forming units) in year one was conducted. A life-long protection (5-years) by the vaccine was assumed (cf. Díaz-Aparicio et al., 2004). Therefore, vaccination was applied only to replacement goats from year two on. Scenario ii consisted of vaccination, test-and-cull at year one. The goat population was assumed to be of a fixed size and culled goats were immediately replaced by brucellosis free replacements. In iii vaccination was as in (i), but test-and-cull was at year 4, after year 4 vaccination stopped. Scenario iv consisted of test-and-cull at year one while no vaccination was applied. In scenarios where testing is being applied, all goats were assumed to be tested. The four scenarios were chosen because they represent the core of the brucellosis control and eradication campaign in Mexico (SAGARPA, 1996).

The initial infected level was assumed to be 20%, the average seroprevalence in the area (Oseguera Montiel et al., 2013). The effective contact rate (β) refers to the rate in which two goats come into effective contact per unit of time. It was estimated with Berkeley Madonna (v. 8.0.1) software using the curve fit function and based on the assumption that an endemic equilibrium occurred at a prevalence of 38%, the seroprevalence of brucellosis in flocks of the region where brucellosis control is lacking (Oseguera Montiel et al., 2013). The transitions from susceptible to infected and from susceptible to protected and the number of goats removed, and vaccinated were calculated in R (R, 2014) with the packages deSolve (Soetaert et al., 2010) and abc (Csillery et al., 2012). The equations and the parameters are presented in appendix A.

4 Census by a NGO Subcomité de Productores de Ovicaprinos del estado de Michoacán

5 Milk processed in 2010 by one renowned company, (personal communication and records from the company)

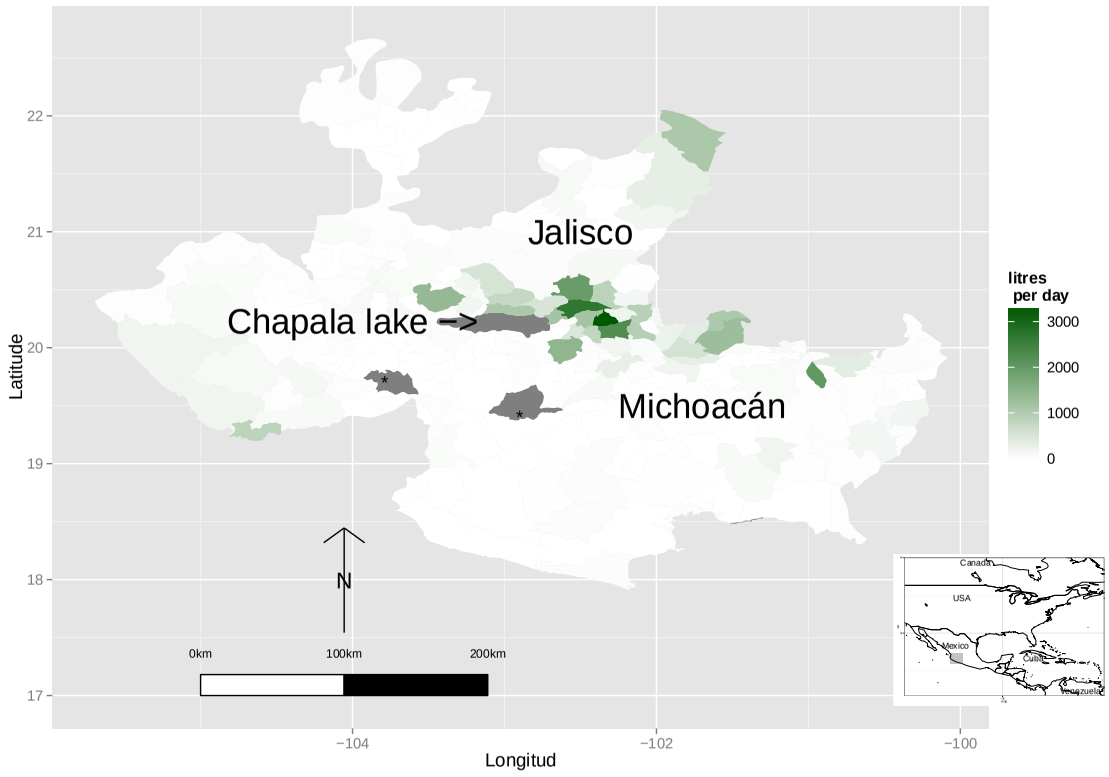

Figure 4.1: Daily goat milk production per municipality. Milk production is higher in municipalities located nearby Chapala lake, an area comprising territories of the states of Michoacán and Jalisco, * indicates missing data. Data source: INEGI (2007)

Table 4.1: Parameter input values used in the simulations of the flock growth model in the Bajío region, Mexico[a]

Production traits	Fixed value/range (minimum, most likely, maximum)[b]
Flock size (head)[c]	(6, 19, 54)
Milk offtake per lactation (l/305-d)	(163, 416, 644)
Litter size (kids/litter)	1.2[d]
Mortality kids (%/year)	17
Mortality adults(%/year)	8
Abortion due to brucellosis (%/year)	20[d]
Goat kid mortality due to brucellosis (%/year)	5[e]
Fertility (%/year)	85[c]
Offtake of female goats (%/year)	16
Offtake goat kids (%/year)	57

[a] Source: Author's unpublished field data
[b] For range values PERT distribution was assigned.
[c] Census data from NGO (unpublished).
[d] One parturition per year.
[e] Authors' assumption.

FLOCK GROWTH MODEL

To estimate the economic impact of brucellosis control programmes a flock growth model was used. Flock growth models measure the performance of livestock production. An indicator for performance is output per livestock unit, which depends on the prediction of the flock structure (i.e. age and sex) (Upton, 1993). To obtain these estimates knowledge of production traits is needed (i.e. mortality, fertility, offtake and yields). The model was developed to examine the effects of brucellosis prevalence level on the output per livestock unit. A main effect of brucellosis in livestock is infertility, which here was defined as the number of live births per doe in a year. The assumption made here was that brucellosis contributes with 20% to the total abortion in the flock, which has implications for the flock structure, goat kids offtake and milk production. Still births, orchitis and mastitis are some other effects of brucellosis, but reliable estimates for these parameters are not readily available. A reduction in fertility means less young surplus for replacement is available which is reflected in a reduction in offtake.

Production traits used in this model are presented in Table 4.1. For this model a smallholder flock of 23 head instead of village flock (1000 head) was used because it represents more accurately the flock dynamics and production of a typical smallholder goat farming unit. The offtake defined as goats sold and culled in a year. Live male goat kids were sold within the first two months after birth. Farmers get their breeding bucks from other sources. Hence, offtake of goat male kids was 100%. An average of one buck per flock is common but bucks were not considered in the structure of the flock. The flock size was composed of female goats distributed into parturition cohorts. Table 4.2 shows the flock structure

Table 4.2: Assumed flock structure for the flock growth model in the Bajío region, Mexico [a]

Parity/age	Number(%)
Zero (Immature female goats)	7(31)
One	5(20)
Two	4(17)
Three	3(15)
Four	2(10)
Five	2(7)
Total (flock size)	23(100)

[a] Field data unpublished. Results were rounded off to the nearest whole number.

considered for the flock growth model. The number of parturitions was considered as an approximation of the age of the goat, parturition one referring to one-year-old goats. A goat's lifespan was assumed to be five years. A flock production growth model was run for each control strategy used in the transmission model (see Appendix B for equations).

FINANCIAL ANALYSIS

Literature considers that diseases have a direct and indirect impact. Direct impacts can be classified as visible and invisible, whereas indirect impacts can be coded as additional costs and revenue forgone (Rushton et al., 1999). A synthesis of the impacts of caprine brucellosis is shown in Figure 4.2. Rushton et al. (2006) suggest also a nuance understanding of disease impact across the animal production chain, which is presented in Table 4.3. Goat smallholders are in the most affected category, they bear most of the consequences of brucellosis in their flocks. However, the impact is felt throughout the goat dairy production chain. For example, the *cajeta* industry receives less milk because of production losses at farm level.

For the economic evaluation of brucellosis control scenarios we accounted the costs and benefits and the change of value of the money over time as explained in Rushton (2009). Direct impacts on milk production, goat kid survival and fertility were calculated. The indirect impacts included the costs of vaccination, testing and compensating farmers for culled animals. We used two decision-making criteria: net present value (NPV) and the benefit/cost ratio (BCR) to assess economic profitability of the interventions (see Appendix C for the equations and table of costs of inputs and animals). The discount rate being conservatively set to 5% in the estimations derives from the average difference (5.3%) between the Mexican Federal Treasury Certificates (CETES) (a government long-term bond rate) less inflation rate in Mexico from 2007 to 2013 (INEGI, 2014b). Monte Carlo stochastic simulation (5000 iterations) using @Risk (Palisade Corporation Version 4.5) in Excel was used to account for uncertainty and variability. Field data were available for the variables flock size, milk yield, and adult goat price. To explore the effect of uncertainty of data values the PERT

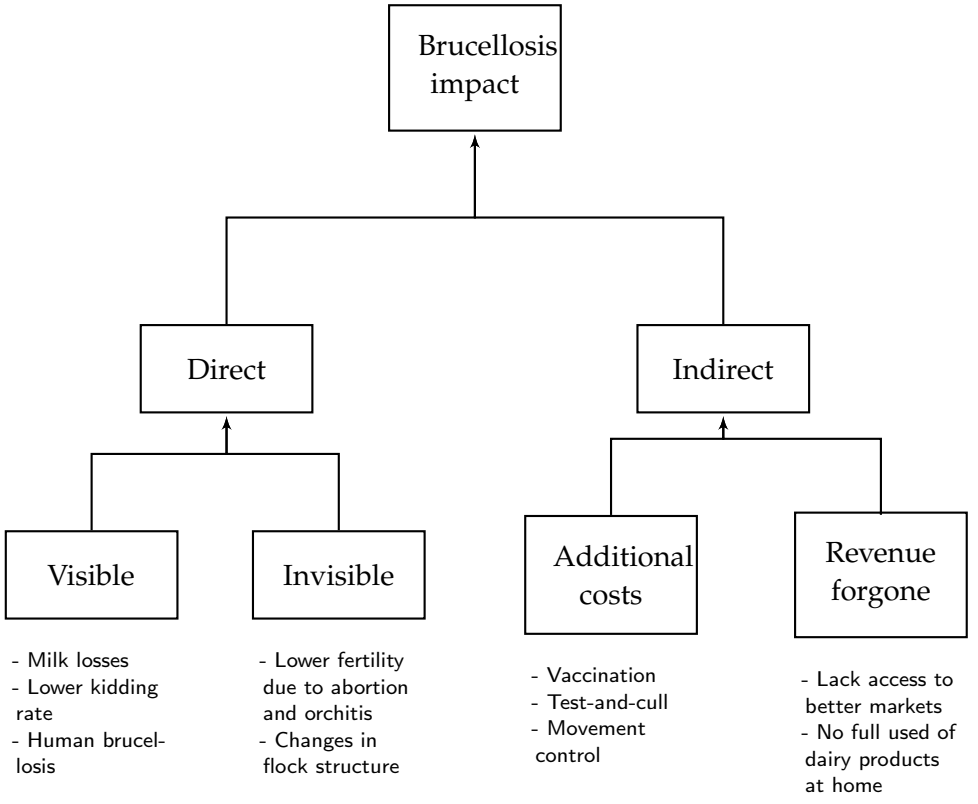

Figure 4.2: Economic impact of caprine brucellosis Adapted from (Rushton et al., 1999)

Table 4.3: Impact of caprine brucellosis on various sectors in Mexico[a]

Sector	Heavy looser	Looser	Winner
Supply	Government subsidizing vaccines, ear tags, tests, etc.	Dairy equipment industry. There are no incentives to adopt technologies due to a vicious circle – low milk quality-low price	Companies involved in vaccine production and antibiotics to treat infections
Production	Smallholders: human brucellosis cases and losses in production due to lower fertility	Cattle, pork and sheep sector at risk due to cross-infections	
Marketing	Smallholders are stuck in a low price dairy market	Entrepreneurs or investors willing to start a dairy cooperative	Farmers with brucella free dairy goat flocks involved in lucrative dairy market, they have less competitors
Processing	Smallholders do not process their own products, losing opportunities to employ their own labour	Caramel industry suffers less supply of milk	Caramel industry pays low for the milk due to the low quality
Consumption	Local consumers do not benefit of a local innocuous dairy product	Urban consumers, do not benefit of a local innocuos dairy product	
General	Goat husbandry sector blamed for human brucellosis. The whole society and government due to the impact on human health	Workers in dairy goat processing industry and slaughter people are in constant risk of getting brucellosis	

[a] Adapted from Rushton et al. (2006)

probability distribution was assigned to the variables. The existing data were deemed as expert data which generally are modelled using a PERT distribution (Vose, 2008). Sensitivity analysis was performed to assess the effect of milk price on the economic criteria. The current milk price MX$4.2[6] was increased with 20% (MX$5.2; US$0.41) in an iterative way until a significant change in the economic criteria was obtained (MX$10.5; US$0.84). Simulation outputs were plotted in R (R, 2014) with ggplot2 (Wickham, 2009).

4.3 RESULTS

BRUCELLOSIS TRANSMISSION

The outputs of the brucellosis transmission model are summarized in Figure 4.3. The baseline scenario b in which no control measures were applied, shows that the number of infected goats increased over time. This number decreased in control measures i and iii, in which no test-and-cull were applied, but at a lower rate than scenarios ii and iv where test-and-cull was applied. Testing and culling in scenario iv reduced the number of infected goats to very low levels. Vaccination alone (i) showed the smallest effect on the prevalence, from 20% in year 0 to about 12% in year 5. The higher impact of the other strategies on seroprevalence from 20% to 1%, was due to test-and-cull. The control strategy (ii), based on vaccination from year 1 to 5 and test-and-cull in year 1, had the largest effect on the reduction of brucellosis prevalence ($< 1\%$) and therefore on the production traits.

FLOCK PRODUCTION

The impact of brucellosis on flock production traits is summarized in Figure 4.4. In the baseline scenario, b, goat kid mortality increased and fertility decreased over the five year study period because the level of brucellosis increased. Flock size increased in all scenarios but less in the baseline scenario. If control strategies were implemented, flock goat kid mortality decreased and goat fertility increased due to the reduction of brucellosis prevalence. The level of improvement varied for each control strategy.

Figure 4.5 shows the milk yields over a five year period. All control programmes had an increasing effect on milk production compared to the baseline scenario where no brucellosis control measures were implemented. Control scenarios ii and iv were shown to have had the highest effect on milk production, with a total increase of 7% more milk over the 5 year period compared to scenario b. Similar to milk yields the flocks grew slightly higher ($\sim$5% from year two onwards) under scenarios ii and iv.

FINANCIAL ANALYSIS OF BRUCELLOSIS CONTROL

Figures 4.6 and 4.7 show the variation of the economic performance of BCR and the NPV criteria of brucellosis control scenarios. Scenario i (only vaccination) predicted an economically superior outcome over the 5-year period. The mean of the NPV was 2.0 and 2.8 for the BCR under the current milk price. For scenarios ii, iii and iv the economic benefits were not satisfactory under the current milk price, only if the milk price increased to MX$ 10.5 control scenario ii and iv became economically rewarding, with the exception of scenario iii which showed the poorest economic results.

6 MX$ 1 = approximately US$ 0.08, £0.04 and €0.05

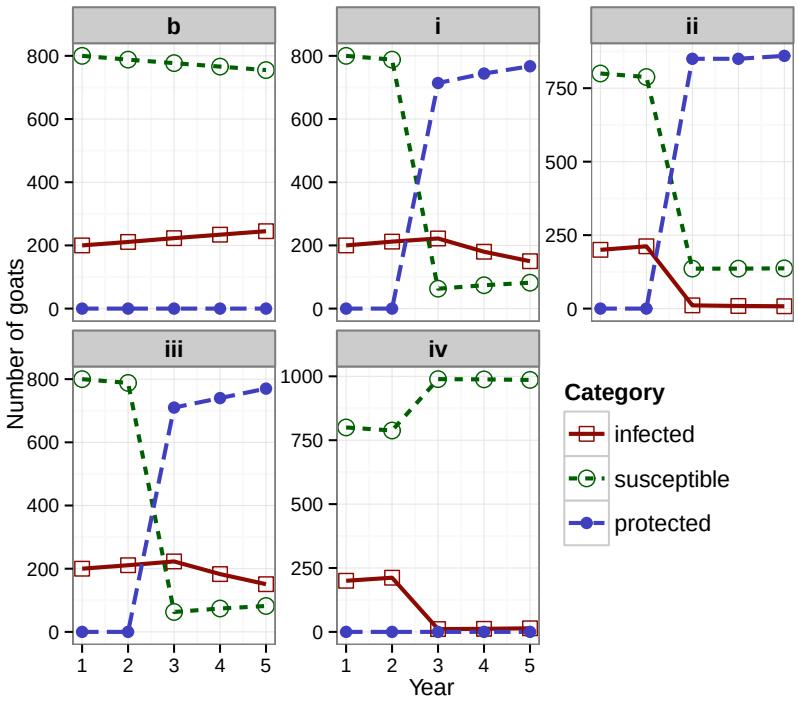

Figure 4.3: Goats infected, susceptible and protected over five years period of a flock under four brucellosis control scenarios: (b) baseline, (i) vaccination, (ii) vaccination, test-culling at year 1, (iii) vaccination, test-culling at year 4, (iv) test-culling at year 1. Number of goats per village = 1000 goats

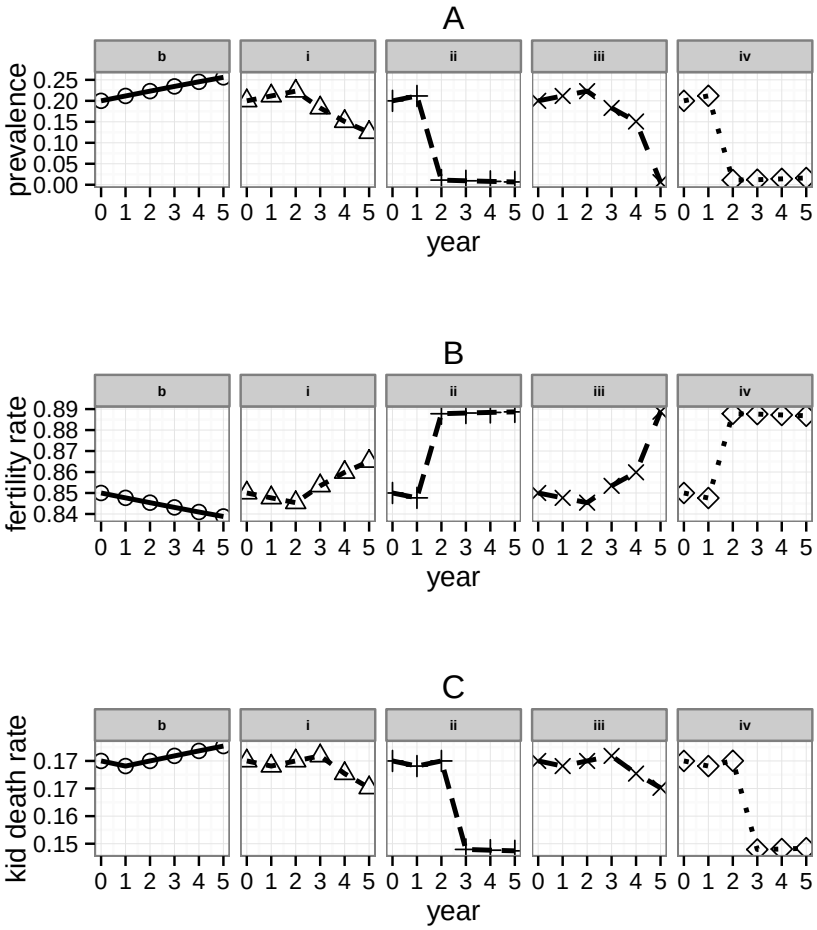

Figure 4.4: Results over 5 year period of the caprine brucellosis transmission model in terms of prevalence (A), fertility rate (B) and goat kid mortality rate (C) under four brucellosis control scenarios: (b) baseline, (i) vaccination, (ii) vaccination, test-culling at year 1, (iii) vaccination, test-culling at year 4, (iv) test-culling at year 1

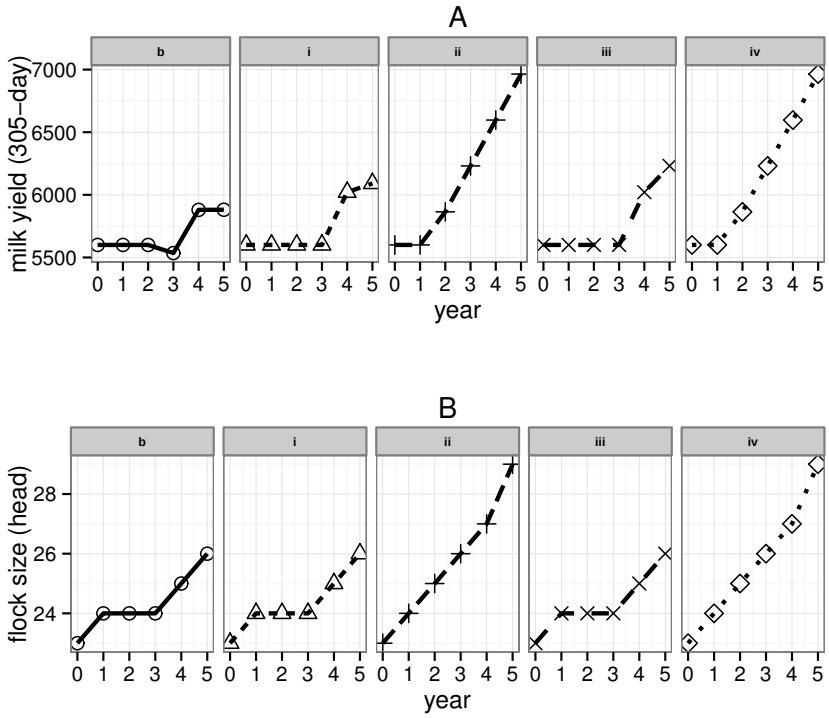

Figure 4.5: 305-day milk production (A) and size (B) of a smallholder flock over a 5 year period under four brucellosis control scenarios: (b) baseline, (i) vaccination, (ii) vaccination, test-culling at year 1, (iii) vaccination, test-culling at year 4, (iv) test-culling at year 1. Plot B) shows the flock growth of an average flock size of a smallholder

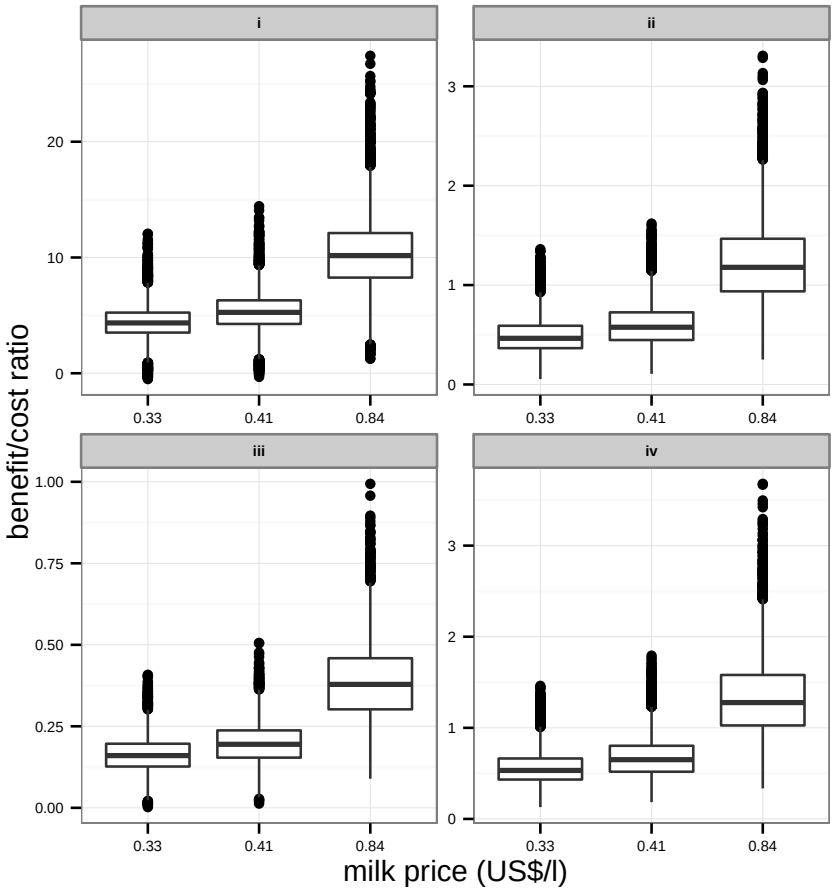

Figure 4.6: Box-Whisker plots of the cost benefit ratio of four control programmes (i: 5-year-vaccination; ii: 5-year-vaccination and test-culling at year 1; iii: vaccination 4-year-culling at year 4; iv: test-culling at year 1) under 3 different farm-gate milk price scenarios, using Montecarlo simulation with 5000 iterations

The NPV criterion of brucellosis control scenarios at a regional level[7] were estimated to be as follows: for scenario i, MX$ 123,078 ($\sim$ US$ 10,000); scenario ii, MX$ -769,240; scenario iii,

7 For our estimation we divided the number of litres of goat milk processed by the two most prominent *cajeta* milk plants in the region by $305 - d$ milk yield, as follow: 16 million litres of milk divided by the average mean milk yield 413.6 yielding 38,462 goats.

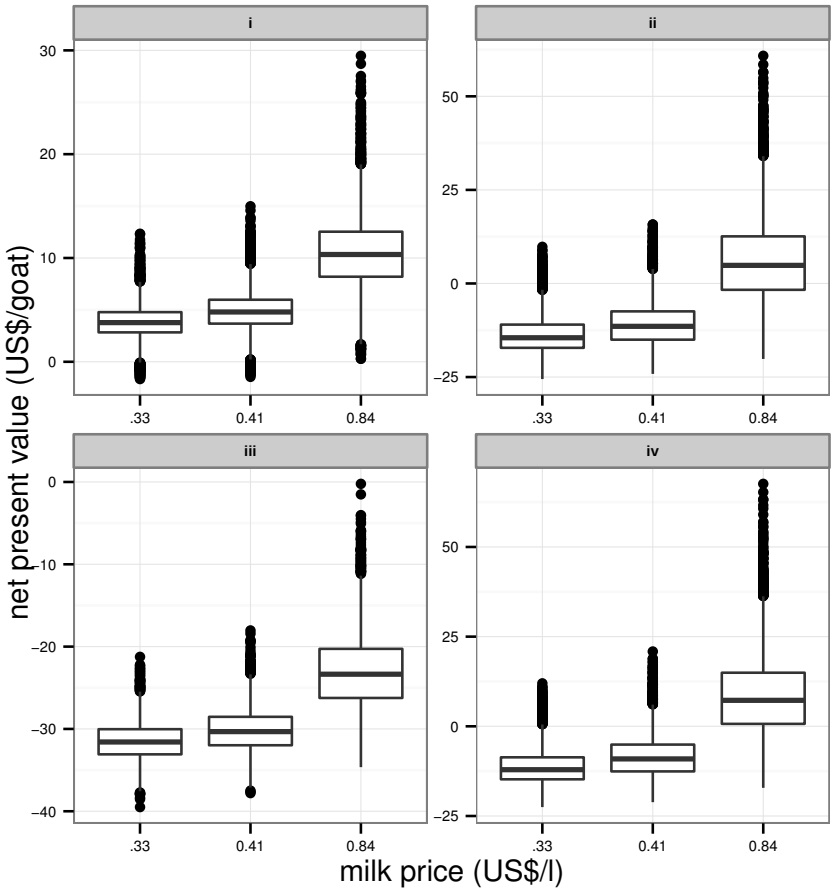

Figure 4.7: Box-Whisker plots of the net present value criterion of four control programmes (i: 5-year-vaccination; ii: 5-year-vaccination and test-culling at year 1; iii: vaccination 4-year-culling at year 4; iv: test-culling at year 1) under 3 different farm-gate milk price scenarios, using Montecarlo simulation with 5000 iterations

-1,226,085; scenario iv, -676,407.2. Only scenario i was positive. The other control scenarios were not economically profitable i.e. they showed negative NPVs. The most unfavourable in economic terms was scenario iii. Scenarios ii and iv were relatively similar ($\sim$ MX$ -600,000). The total costs were more sensitive to variation in the milk yield parameter (99%).

4.4 DISCUSSION

The aim of this study was to investigate the costs and benefits for farmers of several brucellosis control strategies and therefore to understand whether brucellosis control is economically profitable for small-scale goat husbandry in Mexico. Three different models were developed: a flock growth model, a brucellosis transmission model and an economic model. With these models three control scenarios were compared with a scenario where there is no brucellosis control.

Without brucellosis control, the seroprevalence of brucellosis and goat kid mortality increased while the number of live births per doe (fertility) decreased over the five year study period. However, flock size still increased over this period because the combined effects of fertility and mortality did not outweigh goat population growth.

Only the mass vaccination with Rev 1 scenario in the first year followed by vaccination of replacements was economically beneficial when compared to the baseline scenario. Mass vaccination has been recommended as an initial strategy when brucellosis prevalence is high (more than 10% of the flocks infected) or when it is unknown (Blasco, 2010). With scenario i brucellosis prevalence was predicted to be reduced from 20% to 12% which is in agreement with a serological survey in the study area Oseguera Montiel et al. (2013).

Under the time frame we used in this study, it is predicted that brucellosis is likely to persist in the goat population. Therefore, eradication strategies including test-and-cull were considered. Scenarios including test-and-cull reduced brucellosis prevalence to a low level ($< 1\%$). However, these scenarios were associated with high costs and our estimations show that they are not economically profitable at the current milk price. In a small ruminant brucellosis control programme in Portugal, compensating farmers for culling test-positive animals contributed most to all costs (Coelho et al., 2011). Test-and-cull has high initial costs and the benefits of this control strategy are not seen in the short term. Bernués et al. (1997), for example, predicted that the bovine brucellosis control benefits equals costs approximately in 5 to 6 years. Our estimations were done for a relatively short time window. A longer time window would have made control scenarios with test-and-cull less expensive on an annual basis. For example in scenario i in which brucellosis prevalence dropped to 12% a follow-up of five years of test-and-cull may be applied. Therefore, fewer goats would need to be culled per year. Nevertheless, we decided for this relatively short-time period because it reduces the uncertainty of who will still be in goat farming after 5-years and how farming systems will evolve in the next 10 to 20 years. For example due to social instability in region, i.e. violence, goat farmers may also stop farming. State administrations in Mexico last for 6 years and municipalities only 3 years. Also, the uncertainty in estimates will increase when projecting and therefore predicting, over long time period. It is unlikely that individual farmers will look much beyond a five year time horizon. Thus, a 5-year time is realistic to attain to for all parties involved in brucellosis control.

As the analysis predicts negative economic outcomes for scenarios that involve test-and-cull, compensation for culling seropositive goats is needed, which currently is not the case for smallholder goat farmers in the study region. However, scenarios ii and iv can be above the break-even level when the price per litre of milk increases by 60%. Such an increase does not fully compensate for losses in scenario iii (vaccination + test-and-cull) where the specificity of the test is relatively low (80%) for vaccinated animals resulting in unnecessary

culling of non-infected goats. Therefore, combining test-and-cull with vaccination should allow for sufficient time between vaccination and testing to avoid culling of false positive goats.

It would be naive to expect a 60% increase in the milk price under the current market situation. Farmers can be defined as *price takers*, so they must take the price given (Rushton et al., 1999). The goat milk market in the region is an oligopoly of the *cajeta* industry. Furthermore, there is not any milk market incentive; a milk price is set regardless the brucellosis status of the flock. This partly is due to the way milk is processed to produce *cajeta*; by the high temperature applied *Brucella* spp are inactivated.

Our analysis, gives an indication of the impact of brucellosis on goat production and hence on the supply of milk. The companies involved in *cajeta* processing would need to understand that brucellosis causes a reduced milk supply. Furthermore, brucellosis is a serious threat to human health, in this case especially for goat herders, their families and industry employees handling milk. However, the industry does not yet invest in brucellosis control and eradication.

The costs for brucellosis control should also be mirrored against the cost for public health. High economic benefits are reported when the impact of brucellosis in humans was quantified in Mongolia (Roth et al., 2003). Our analysis did not extend to this area largely because of the difficulty of obtaining accurate data on human brucellosis cases that can be attributed to *Brucella spp.* infected goats. In the province hospital of La Barca in the state of Jalisco (located in the region of the study) from January to October 2009, 3 out 20 human brucellosis seropositive patients had direct contact with goats (Dr. Marco Rodríguez, personal communication). While this information gives some indication of the dimension of human brucellosis due to brucellosis in goats the real impact is likely to be larger because people in rural communities do not always have access to good medical services and there is not a brucellosis surveillance system in place for humans.

The brucellosis transmission model was applied to a village goat flock. In rural villages of the region cattle husbandry is also common. Goat flocks have direct and indirect contact with cattle herds because they are herded to graze and visit goat grazing areas too. Circulation of the bacterium *Brucella spp.* between goats and cattle therefore is likely in mixed farming (Al-Majali et al., 2009) especially when there is no vaccination programme applied. Our model did not include cattle because of the lack of data on brucellosis in cattle. Further studies are needed to assess the role of mixed farming in the transmission of brucellosis among domestic species; i.e. raising goats along with cattle in villages of the region.

The sensitivity analysis of the economic model showed that milk yield was the most important parameter for our economic estimations of NPV and BCR. Milk yield data range was large, however, more detailed data on milk yields by goat parity could have given better estimates. Nevertheless, our study shows that the benefits of brucellosis control can accrue in terms of goat production.

The modelling approach used here to describe the impact of different control strategies is useful to understand the economic impact of brucellosis and its control. These models can be used in other parts of the country or in other countries of the global South where smallholder goat husbandry is similar to the one described here. The brucellosis transmission models can predict the dynamics of brucellosis in the goat population. In the long run with the aim to eradicate brucellosis, scenario ii (vaccination, test-and-cull at year 1) should be chosen.

Brucellosis control will need active participation from the *cajeta* companies, government, and farmers.

4.5 CONCLUSIONS

Brucellosis control based on a strategy of vaccination alone is predicted to be economically profitable for goat farmers. For a five-year period a NPV was MX$ 123,078 ($\sim$ US$10,000) was estimated at a regional level. The analysis indicated that control strategies based on test-and-cull were not economically profitable, yet they were more effective in reducing brucellosis prevalence ($\leq$ 3%) than vaccination alone. Such a reduction in the goat prevalence would probably have a direct impact on public health, especially with the high risk groups in society such as goat farmers, dairy industry and slaughterhouse personnel. Financial support is needed to help farmers to achieve a significant reduction with regard to caprine brucellosis. The *cajeta* industry needs to be involved in brucellosis control like paying a bonus for milk from brucellosis free flocks, as brucellosis has an effect on flock productivity and therefore on the amount of milk produced. Further studies that consider the impact of brucellosis on public health are needed.

4.6 APPENDIX A. TRANSMISSION MODEL STRUCTURE AND EQUATIONS IN BRUCELLOSIS

Table 4.4 shows the inputs used in the transmission model. The model structure and the transition equations are shown in Figure 4.8.

Table 4.4: Inputs used in the compartmental deterministic epidemiological model for brucellosis transmission in goat flocks of the Bajío region, Mexico

Input parameter	Symbol	Value
Culling rate per year	mu_g	0.2
Rate at which two individuals come into effective contact	β	0.00040311
RBT sensitivity	se	0.95[a]
RBT specificity non vaccinated goats	sp_{unvx}	0.99[b]
RBT specificity vaccinated goats	sp_{vx}	0.80[c]
Proportion of vaccinated goats that seroconverted	scg	1
Vaccine efficacy of Rev 1	ve_g	0.86

[a] Díaz-Aparicio et al. (1994) reported a 100% sensitivity of a modified RBT, here we set it to 95%
[b] (Nielsen et al., 2004)
[c] (Díaz-Aparicio et al., 1994)

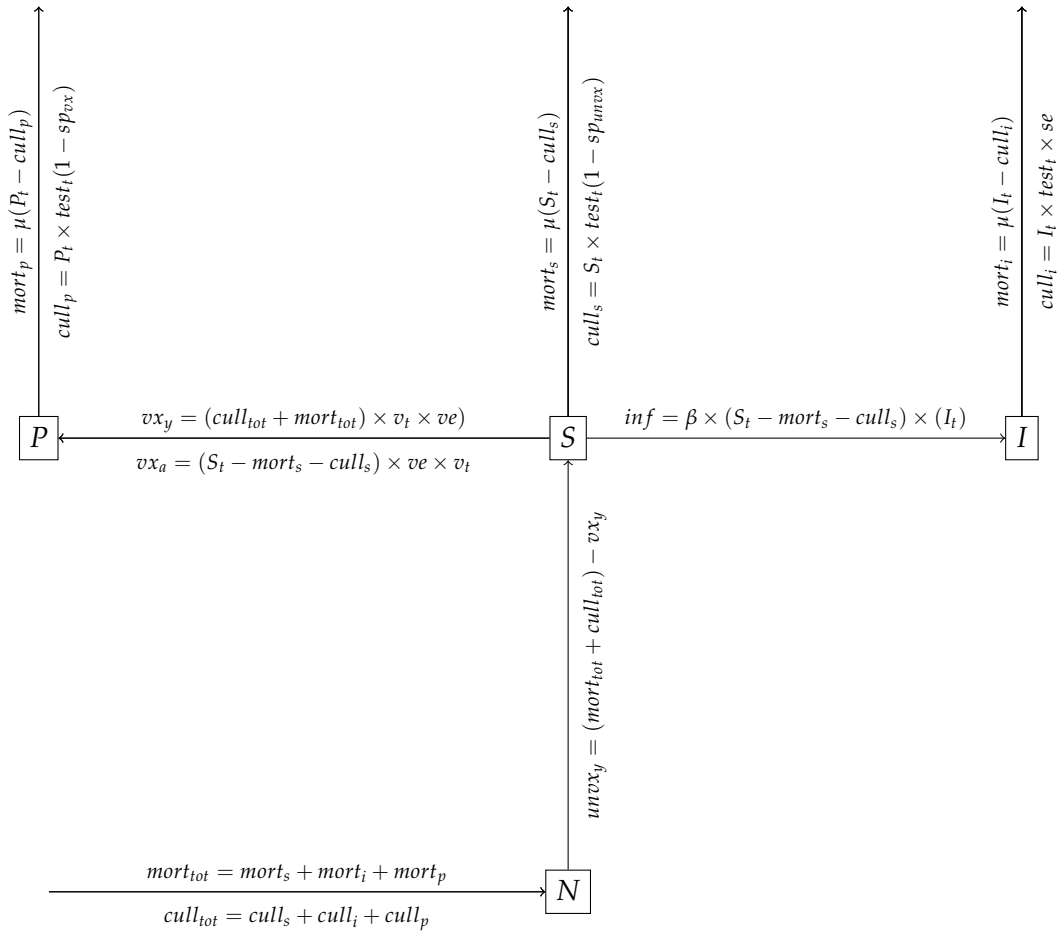

Figure 4.8: Model structure and equations for the simulation of brucellosis transmission in a village goat flock (n = 1000 head) in the Bajío region, Mexico. The goat population is divided in four compartments: susceptible (S), infectious (I), protected (P) and replacements (N). Where $mort_p$ = deaths of protected; P_t = number protected at a given time (t); $cull_p$ = culled protected; $test_t$ = proportion of tested goats at a given time t; sp_{vx} = specificity for vaccinated goats; $cull_s$ = culled susceptible; sp_{unvx} = specificity of the test for non vaccinated goats; $mort_s$ = susceptible died; $cull_i$, culled infected; se, sensitivity of the test; $mort_i$, mortality infected; tot_{mort} = total deaths; tot_{cull} = total culled; vx_y = young vaccinated; ve = vaccine efficacy; vx_a = vaccinated adults; inf = infected; β = rate of effective contact, and $unvx_y$ = number of young non vaccinated

DIFFERENCE EQUATIONS

The brucellosis transmission model consists of the following difference equations:

$$S_{t+1} = S_t + unvx_y - cull_s - mort_s - inf - vx_a$$

$$I_{t+1} = I_t + inf - cull_i - mort_i$$

$$P_{t+1} = P_t + vx_y + vx_a - cull_p - mort_p$$

4.7 APPENDIX B. EQUATIONS USED FOR THE FLOCK GROWTH MODEL

The fertility was determined as the number of live births in a year period; a year is the parturition period:

$$F_i = \frac{B_i}{D_i}$$

where F_i is the fertility in a year i, B_i is the number of births in a year i, and the D_i is the number of does in a year time. The equation to calculate the number of goat head (H_{ij}) per cohort was the following:

$$H_{ij} = G_{ij} - (G_{ij} \times M_{ij}) - (G_{ij} \times O_{ij})$$

where G_{ij} refers to the number of goats per category i at each parturition j, M_{ij} is mortality rate i per category at each year j, and O_{ij} is the offtake rate per category i at each year j.

The milk yield Y_i per year was calculated as follow:

$$Y_i = \sum_{i=1}^{5} B \times F_i \times M_i$$

where B is number of breeding goats in a year i, F_i is fertility rate in year i and M_i is the does mortality rate in a year i.

Goat kids offtakes K_i was calculated as follow:

$$K_i = \sum_{i=1}^{5} B \times (L \times F_i) \times T)$$

where T is the goat kids offtake rate. L is the litter size. And offtakes of adult goats (U_i) was given by:

$$U_i = \sum_{i=1}^{5} B \times V$$

where V is the offtake rate of does.

4.8 APPENDIX C. EQUATIONS FOR THE FINANCIAL ANALYSIS

Table 4.5 shows the costs of animals and inputs for brucellosis control. All costs given below were obtained directly from the study area during 2008 and 2009.

Table 4.5: Prices (in MX$) used for the financial analysis for the Bajío region[a]

Inputs	Fixed value or range (minimum, most likely, maximum)[a]
Inputs	*MX$*
Vaccine Rev 1 standard dose	10
Goat breeding replacements price	2650
Male goat kid price	270
Culled goat adult price	(600, 700, 900)
Rose Bengal test price	15

[a] Source: Authors' unpublished field data

The NPV was calculated with:

$$NPV = \sum \frac{B_t}{(1+r)^t} - \sum \frac{C_t}{(1+r)^t}$$

where B is benefits (in money) in a year t, r is the rate of discount (i.e., 0.05) and C is the costs.

The BCR was calculated as:

$$BCR = \frac{\sum \frac{B_t}{(1+r)^t}}{\sum \frac{C_t}{(1+r)^t}}$$

5

'LA FIEBRE MALTA': AN INTERFACE OF FARMERS AND CAPRINE BRUCELLOSIS CONTROL POLICIES IN THE BAJÍO REGION, MEXICO

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ABSTRACT

Brucellosis is a worldwide zoonosis, but the major burden is thought to be among the smallholder farmers in the global South. Using a case study of brucellosis control in goats in the Bajío region, Mexico, this paper shows that socioeconomic factors, defined here as practices, knowledge, interests, beliefs and experiences have a role in the adoption of brucellosis control strategies. We combined qualitative and quantitative methods to show how socioeconomic factors with regard to goat husbandry and brucellosis control are not taken into account in the current policy for brucellosis control in Mexico. Farmers rank constraints like the price of goat milk more important than the control of brucellosis. The impact of brucellosis on goat production is hidden to farmers and the term brucellosis is still a strange name to them; it is known better as *'la fiebre Malta'* (Malta fever), which farmers are aware of and which they avoid by not drinking goat milk. Brucellosis control measures cause losses such as abortion due to vaccination and ear infections due to ear tagging. In the villages of the state of Michoacán the uptake was almost complete because the service was free, whereas in villages of Jalisco vaccination was not adopted thoroughly because for farmers the cost of vaccination was high and because there was a lack of veterinarians offering the services. Compensation for culling suspected infected goats does not exist nor the infrastructure either, e.g. slaughterhouses, to ensure that goats that are brucellosis seropositive are not resold to neighbouring farmers. This paper disputes the idea that brucellosis is confined to the lack of awareness and participation of farmers in control measures, but rather that policies are promulgated without a good knowledge of goat husbandry and farmers perceptions. It is a two way lack of communication, farmers do not know exactly what brucellosis is about and worryingly policies are promulgated without knowing thoroughly farmers perceptions based on socioeconomic factors. We claim that governmental authorities should reformulate the policy to take into account socioeconomic factors shaping farmers' behaviour so that effective control measures will be adopted by goat farmers.

Keywords: brucellosis, socioeconomic factors, goats, Malta fever, Mexico, 'One health', zoonosis

5.1 INTRODUCTION

Brucellosis caused by the bacterium *Brucella* spp. is the most common zoonotic infection spread worldwide (Pappas et al., 2006). Eight species of *Brucella* are identified (Sriranganathan et al., 2009). The most common pathogens in decreasing order of their incidence in humans are *B. melitensis* (small ruminants), *B. suis* (pigs) and *B. abortus* (cattle) (Lucero et al., 2008). The control of brucellosis in livestock correlates with a reduction of infections in humans, but a main issue is that eradication programmes are not easily successful (Minas et al., 2004). Despite a wealth of knowledge about brucellosis control such as causal pathogen, risk factors, serological tests to detect animals exposed to *Brucella* and prevention through vaccination, brucellosis remains endemic in small ruminants, cattle and camelid populations of the global South and south and central Europe (OIE, 2004). Economic losses in livestock production are mainly due to a reduced fertility. In humans brucellosis causes fever and complications in any organ system (Corbel, 2006).

Mexico is one of the many countries where brucellosis is of national importance and therefore human as well as animal cases are notifiable (SAGARPA, 1996; SSA, 2012). Brucellosis control in Mexico started in 1971, but it was not until 1996 before a policy made the control compulsory for all cattle and small ruminant keepers (SAGARPA, 1996). Brucellosis seroprevalence in livestock, however, is over 3% in most states of the country and there is little progress in control in recent years (Luna-Martínez and Mejía-Terán, 2002; SENASICA, 2012). Only the northern region of Sonora state is declared as brucellosis 'free', and in a few other areas of the south and the southern region of Sonora and Baja California Sur, the prevalence is relatively low ($< 3\%$).

Brucellosis incidence in the human population at national level is reported to have declined from 3,008 cases in 2007 to 2,157 in 2012 (SSA, 2014), however, in central west states of Mexico the incidence is increasing. For example, in the state of Jalisco 83% more cases were diagnosed in 2012 (n = 192) compared to 2007 (n = 105), and in the state of Michoacán 42% more (n = 67 in 2007 and n = 95 in 2012) (SSA, 2014). Caprine brucellosis is endemic in these two prominent goat keeping states of the Bajío region (Oseguera Montiel et al., 2013).

The poor results of brucellosis control might be related to the lack of compliance with preventive measures for brucellosis, i.e. vaccination, test-and-cull. Brucellosis control measures are imposed on farmers. Top down approaches towards disease control can cause confrontations when interests of stakeholders do not match (Zinsstag et al., 2005); see e.g. Reséndiz Torres (1999) for the uproar around the Foot and Mouth Disease outbreak in Mexico in the 1950's. Minas (2006) states that control/eradication of brucellosis is both science and art. The science part involves the knowledge of the disease, i.e. epidemiology, vaccines and serological tests and the art is about being able to implement the control measures that are acceptable to the stakeholders, e.g. farmers (Minas, 2006). The literature provides rather explicit instructions in the steps for the control and eradication of brucellosis in small ruminants, i.e. vaccination and test-and-cull (e.g. Blasco, 2010). However, the art part to succeed in the control and eradication is lacking for many specific situations in many countries where the disease is endemic.

The present study aims to shed light on this art part. The adoption of measures for brucellosis control can involve socioeconomic factors e.g. beliefs, behaviours, knowledge and interests of local people as is the case with agricultural innovations (Ruttan and Hayami,

1984). In general this paper aims to show the current state of and barriers to brucellosis control in goats in the Bajío region, Mexico. In particular we illustrate farmers' perceptions and socioeconomic factors that play a role in the adoption of policies for brucellosis control.

5.2 BRUCELLOSIS CONTROL AND SOCIOECONOMIC FACTORS

Disease control policies are often based on epidemiological research, such as disease spreading modelling and risk factor analysis, but socioeconomic factors are rarely considered in the design of the policies. However, the understanding of socioeconomic factors in health is important to build better epidemiological models and can also help to understand the successes and failures in current policies (Leach and Scoones, 2013). For example, Hewlett and Hewlett (2008) show the importance of understanding people's beliefs and practices with regard to Haemorrhagic Ebola virus because, those beliefs and practices are related to disease spreading and to the uptake of control measures.

The theory of social construction of reality developed by Berger and Luckman (1966) has been sugested to understand social factors with regard to health issues (Kleinman, 2010). In a pragmatic way of looking at their theory, it explains how in each 'local world' - household, village, nation, country, network of physicians- a health issue can have a different meaning for people depending on the setting. As Kleinman (2010) exemplifies, a health issue can be contentious in one country but not in the other, which depends very much on socioeconomic factors. Based on this theory Boogaard (2009) assessed the perceptions of Dutch citizens with regard to dairy farming. Boogaard used a frame of reference based on interests, knowledge, experiences and values. A frame of reference with regard to disease control, however, can include other factors like beliefs and practices (Hewlett and Amola, 2003; Hewlett and Hewlett, 2008). Here we make use of a frame of reference based on goat farmers' interests, knowledge, experiences, beliefs and practices in regard to brucellosis control.

Figure 5.1 shows how farmers are embedded in a complex context in which they build their frame of reference. The bottom level represents farmer's perceptions, influenced by socioeconomic factors. These factors are influenced by the physical environment, e.g. ecology, infrastructure (Dixon et al., 2013). But also by policies that are promulgated at national and global level. Policies determine the access to resources, infrastructure and rules (e.g. restricted transportation of animals), however, some policies derived in actions or interventions that can have unintended consequences and which can be negative. People's frame of reference is based on such experiences, which can lead to individual and community resistance to intervention programmes (Kleinman, 2010). Here we pay attention to how policies with regard to brucellosis control are perceived by farmers.

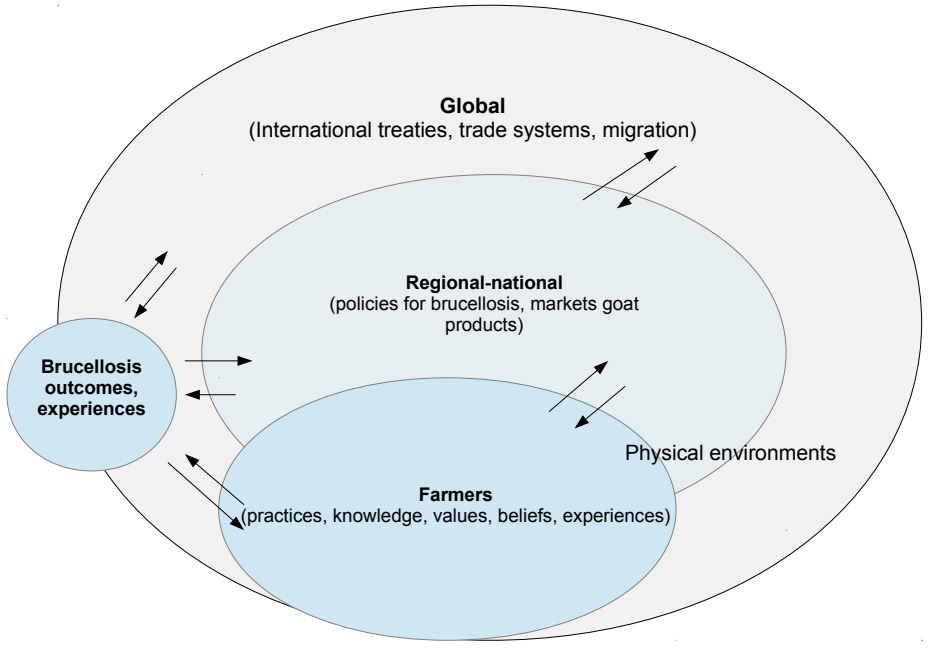

Figure 5.1: Different levels at which socioeconomic factors can have an influence on brucellosis outcomes and experiences. Adapted from Dixon et al. (2013)

5.3 BRUCELLOSIS CONTROL IN MEXICO

In Mexico the brucellosis control policy is described in a mandate from 1996 known as *Norma Oficial Mexicana NOM-041-ZOO-1995, Campaña Nacional contra la Brucelosis en los Animales* (SAGARPA, 1996). The document describes the steps to be taken for control and eradication of brucellosis in cattle and small ruminants. It is obligatory for all farmers keeping ruminants to take part in the campaign, but also for local governments an active role is stated. Two distinct levels of actions and status with regard to brucellosis in livestock can be differentiated: 1) the regional level in which governmental authorities have a role and 2) the flock or herd level in which farmers have a role. Table 5.1 shows the activities and the several stages of control of *B. abortus* and *B. melitensis* at the two levels.

A region, which can be a state or one or various municipalities within one state, is classified according to the level of progress in the control of brucellosis in the following categories: (1) control stage (prevalence is above 3% or unknown), (2) eradication (prevalence is under 3%) and (3) free (no brucellosis). Control and eradication activities at flock level focus on vaccination, test-and-cull. Animals tested and vaccinated need to be identified, normally by

an ear tag. A goat testing positive to brucellosis, has to be branded with 'B' in the right cheek.

FUNDING

Funding for control activities at flock level is meant to be shared among the federal government, local governments (i.e. states and municipalities) and the farmers. The national budget in 2008 was 89 million pesos (MX$)[3]. If divided by the total number of cattle and small ruminants in the country, this budget equals 2.5MX$ per head. The budget at national level has been increasing, in 2008 the budget was 243% higher than in 2001 (CONASA, 2008).

Federal funds for the campaign are budgeted from the agriculture support programme *Alianza para el Campo* (alliance for agriculture). From this programme, funds are channeled to *Comités de Fomento y Protección Pecuaria* (state committees for livestock production and protection). Committees are a decentralized and registered organization in Mexico. Farmers are meant to pay one third of the costs, the other two thirds come from the committees and local governments (Luna-Martínez and Mejía-Terán, 2002).

IMPLEMENTATION

Mexico has 31 states and one federal district (Mexico City). The brucellosis campaign is implemented according to a state plan and in each state a committee coordinates the control measures, which are based on the state's priorities; e.g. for the state of Sonora bordering the US, cattle for export are a main driver to control bovine brucellosis. Luna-Martínez and Mejía-Terán (2002) state that brucellosis campaign activities in Mexico follow the local characteristics of livestock husbandry which are being shaped by a large diversity of agro-ecological conditions of the country. Mexico is a country of contrasts in their livestock production systems. These can vary from low external inputs systems which are based on family labour and extensive grazing, to high external inputs systems; where livestock are kept indoors and which requires hired labour.

The operation of the brucellosis campaign relies on veterinarians who have been certified for brucellosis control by the agricultural secretariat (SAGARPA) by means of an examination. They play a central role, because they are the only authorized people to supervise and/or apply control actions such as testing and vaccination and they are also responsible for signing a report of the activities, e.g. number of vaccinations and tests that have been carried out. At the end of 2013, Mexico counted 2,784 certified veterinarians and if these veterinarians were entitled to work in goats only, the flock:veterinarian ratio would be 93:1, with a goat head: veterinarian ratio of 1436:1 (SENASICA, 2013). Certified veterinarians are also entitled to work in the tuberculosis campaign for cattle. The number of veterinarians actually dealing with brucellosis control within a specific livestock sector is not precisely known.

A committee can have its own team of veterinarians or rely on private veterinarians who take part in brucellosis control activities as an income source, often besides their regular work in their veterinary clinics or shops. In general, committees supply veterinarians inputs, i.e. vaccines and antigens to perform serological testing and metal ear tags at no costs. Then veterinarians make a living by selling their services, e.g. vaccination to farmers, who they approach on their own initiative. Often the activities for brucellosis and tuberculosis

3 In 2008 the exchange rate of a Mexican peso (MX$) US$ 0.08, € 0.06 and £ 0.05 (Banxico, 2008)

Table 5.1: Steps for brucellosis control and eradication in Mexico at two levels: regional and flock/herd. Data source: (SAGARPA, 1996)

	Regional		
	Control	Eradication	Free
Brucellosis status			
Brucellosis seroprevalence	$> 3\%$ or unknown	prevalence is $< 3\%$	Free
Activities & infrastructure			
Census of flocks/herds	development stage	updated	updated
Control of movement	yes	strict, must have check points	yes
Vaccination	yes	yes	optional
Surveillance system (SIVE)	yes	yes, also in slaughter houses	yes
Veterinary services and labs	yes	yes	yes
Campaign promotion	yes	yes	monitoring
Subscribed herds and flocks	yes	100%	100% brucellosis negative
Culling seropositive animals	yes	yes	-
Controlled production farms[a]	optional	-	-
Slaughterhouses	-	-	yes
	Flock/herd		
	Control	Control-intensive	control-eradication
Interventions			
Vaccination	Yes	Yes	Yes
Testing	-	Yes	Yes
Culling seropositive	-	-	Must

[a] Seropositive dairy livestock in production can be sent to these farms. At the end of the production cycle animals are culled.

control are carried out in parallel by the same veterinarian which can be more attractive for veterinarians because they can obtain revenues for providing services to control both diseases.

Besides the committees, brucellosis control can be organized through an extension service called '*GGAVATT*' (farmers group for validation and transfer of technologies). Usually these groups are coordinated by a veterinarian, whose salary is paid by the government (90%) and by farmers (10%). The governmental support for the GGAVATT lasts three years and thereafter farmers are expected to hire the veterinarian with their own funds.

5.4 METHODS

The field work was conducted in the period 2007-2009 and was based on a mix of qualitative and quantitative methods: secondary data review, participatory observations, focus group discussions in six villages, in-depth semi-structured interviews with farmers (n = 11) and other stakeholders, i.e. veterinarians, creamery owners, caramel industry employees, physicians and a nurse (n = 8), numerous informal conversations, two cross-sectional surveys, one among 46 farmers (to assess their views regarding brucellosis) and a second one among 88 farmers (to assess their knowledge of brucellosis) and one longitudinal survey for a year among 46 farmers (to assess production parameters). The first author is a licensed veterinarian in Mexico and certified for the control of brucellosis at the time of the research. He introduced himself as such to the farmers explaining the goals of the research. This was deliberately done to prevent false expectations among farmers like considering the researcher as a source of veterinary drugs or a state employee bringing public support. The researcher was prepared to provide veterinary examinations in goat flocks upon a farmer's request. This created an entry point to gain more insights in goat farmers' values, practices and knowledge towards brucellosis.

For focus group discussions data were collected until saturation was reached, i.e. when no new data or insights were obtained. Ten meetings were organized in villages. Approximately 10 to 15 farmers attended each meeting, mostly males heading the farm. Two women were present in one of the meetings. The discussions covered the following: first, how farmers perceived the need to control brucellosis in relation to other issues related to goat husbandry and second, a discussion about goat diseases, which involved identification and ranking their importance in relation to brucellosis. A drawing of a dairy goat on a large paper (Ao size) and a pencil were provided to farmers who were then asked to point out which body parts of a dairy doe were affected by the various diseases that farmers had to deal with. Second, strategies for brucellosis control in the village/region were explained. Farmers were updated with brucellosis transmission topics, i.e. cross infections among different livestock species and different ways of transmission from animals to humans. Farmers shared their views on how brucellosis should be controlled. Third, they discussed how goat husbandry practices and brucellosis risk factors related to grazing practices.

SETTING: PHYSICAL ENVIRONMENT

The study was conducted in the western area of a central region of Mexico known as Bajío. The Bajío comprises territories of four states: Guanajuato, Querétaro, Michoacán and Jalisco. It is a volcanic area, but renowned for the production potential of its soils in the valleys.

Cropping is associated with livestock husbandry, e.g. goat husbandry since the colonial times in the sixteenth century. The hills of the volcanoes are often communal land, used for subsistence cropping and offer a relatively abundant feed source for free-range cattle and goats kept under extensive grazing systems (Oseguera Montiel et al., 2014a). In the valleys intensive high input crop production takes place and this offers a relatively abundant source of feed for small-scale dairy cattle and goat husbandry systems in the form of crop residues in the dry season. The study locations were three villages in Michoacán state and two in Jalisco state. These were purposely selected, first because of the presence of small-scale goat husbandry systems and second because brucellosis control schemes were different between Michoacán and Jalisco. The field work started in the villages of Michoacán in 2007. Villages of Jalisco were included in the study in 2008 when it was decided to compare the experiences of brucellosis control in Michoacán with Jalisco. Hence, a survey about farmers opinions on constraints in brucellosis control was carried out in Michoacán but not in Jalisco.

BRUCELLOSIS CONTROL SETTINGS IN MICHOACÁN AND JALISCO

In the villages of Michoacán brucellosis control in goats was led by an association/committee, which is further refered to as 'CM' (pseudonym), which was a branch of the state committee of Michoacán. CM hired veterinarians to conduct activities related to brucellosis control. In 1999 CM reported that 8,000 goats were vaccinated against brucellosis. The proportion of goats vaccinated from 1999 to 2004 is shown in Figure 5.2 (plot a). In 2003, the number of vaccinations was 60,000, the highest number in the period from 1999 to 2004, and covering about 43% of the total number of goats in the whole state[4]. The work of the committee was centred in a basin area of Chapala lake and Lerma river, which is part of the Bajío, and where goat density is high. The percentage of flocks under control (vaccination) was above 90% in the villages where the study was conducted.

In Jalisco the activities for control were led by the association/committee, which is further refered to as CJ. CJ did not have a branch focusing on small ruminants as in Michoacán. They had however, a branch office in the study region. The control activities (i.e., vaccination, testing) were done by private veterinarians, and farmers had to pay the veterinarians for vaccinations and blood sample testing. Vaccinating a goat did cost 10 MX$ pesos per head and testing 10 to 15 MX$. Table 5.2 summarises some characteristics of the campaign for brucellosis control in the study area. Compared to Michoacán the campaign in Jalisco was negligible and the proportion of seropositive goats to brucellosis was higher: 38%, in Jalisco versus 12% in Michoacán.

DATA ANALYSIS

Interviews were audio recorded and transcripts were coded in themes. Quantitative data from surveys, i.e. importance of goat diseases, knowledge about brucellosis, goat production and health inputs were analysed for statistical differences between Michoacán and Jalisco. T-test was used for means and χ^2 for proportions. Statistical analyses were done with R (R, 2014), graphs were plotted with ggplot2 (Wickham, 2009).

4 The reduction in the number of vaccinated goats in 2004 observed may relate to the use of funds for a serological survey conducted by the committee in that year

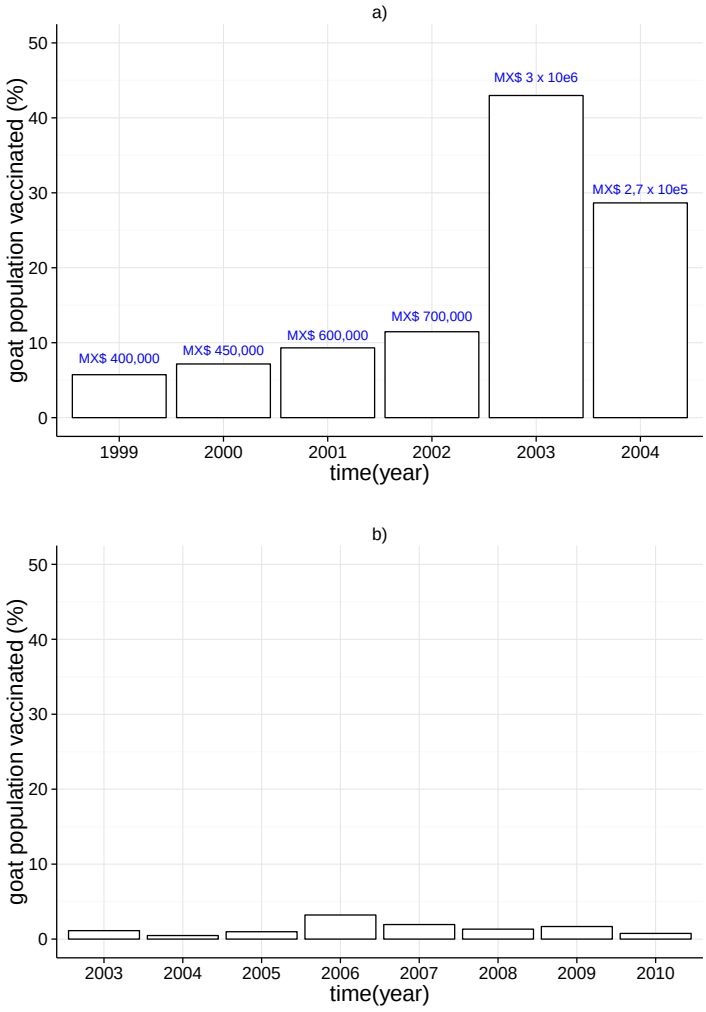

Figure 5.2: Goat population vaccinated in Jalisco and Michoacán states. Plot a, Michoacán's state goat population vaccinated, budget in Mexican pesos (MX$) per year shown on top of the bars, data source: (Bazán Rodríguez, 2009). Plot b, Jalisco's state goat population vaccinated, data source: (COEETB, 2013). For plots, the assumption was made that only goats were vaccinated and no sheep

Table 5.2: Brucellosis control characteristics in the study area Michoacán and Jalisco

	State	
	Michoacán	Jalisco
Census of flocks	Yes	No
Vaccination costs for farmers	Free	10 MX$
Seroprevalence of brucellosis[a]	12%	38%
Serological testing	5000 head	negligible
Vaccination coverage[b]	$\geq$ 90%	negligible
Committee	CM	CJ
Distance from villages to offices	$>$ 150 km	$<$ 20 km
Goal	goats	cattle and small ruminants
Brucellosis vaccination for cattle	-	yes
GAVATT in villages visited	yes	no

[a] Source:(Oseguera Montiel et al., 2013)
[b] Refers to the study area only

5.5 RESULTS

GOAT HUSBANDRY

Qualitative methods revealed farmers' practices. In general, goat flocks are kept in extensive grazing systems. In Michoacán goat husbandry is a sedentary system, flocks graze in crop and communal land and/or nearby villages, whereas in Jalisco goat husbandry is based on semi-transhumant pastoral systems. Goats are milked by hand once per day in the mornings, pens are often next to farmers' houses and during transhumance the farmers sleep next to their goats pens. Flocks are herded to areas far from a village for grazing. During the rainy season (July to September) flocks from both states graze on communal land in the hills and sometimes along road sides. In the dry season (October to June) flocks graze residues on crop land. Jalisco's farmers travel to other villages to have access to crop residues. During grazing contact with other goat flocks is common as well as with other livestock species. Herding goats is a man's job.

FLOCKS STRUCTURE, PRODUCTION AND MARKET

Table 5.3 shows the flock structure of goat farms in both states. Goat husbandry was dairy oriented and thus does predominate in the flocks. Jalisco flocks had significantly less bucks and their goats had higher milk production compared to Michoacán flocks. Flocks are mostly crossbreds of Criollo goats with exotic goat breeds, i.e. Saanen and French Alpine. Saanen goats are known by farmers as 'güeras' (meaning blond). Formerly, goat flocks were made up of brown and black local breeds, most likely Criollo goats, descending from Spanish breeds. Senior farmers reported that they started to use bucks of exotic breeds in the 1970s and 1980s. They also mentioned that these breeds were promoted by the *'cajeta'* (caramel) industry that

processes goat milk. In general farmers have their own buck(s), however, during the mating season bucks also mate does from neighbour's flocks.

Table 5.3: Comparison of goat flock structure of the states of Michoacán and Jalisco, Mexico

	Michoacán (n = 25)		Jalisco (n = 21)	
	mean	SD[a]	mean	SD[a]
does	63.5	74.8	71.2	52.0
young stock[b]	21.4	13.6	23.5	19.7
bucks[*]	2.3	1.7	1.5	1.2
head	87.2	87.8	96.2	70.0
does:buck ratio	27.3	13.6	44.4	31.9
milk (litres per day, per goat)[*]	0.70	0.30	0.94	0.30

[a] Standard deviation
[b] Goats < one-year-old
[*] Denotes significant difference between means of the two states (t- test $P < 0.05$)

Table 5.4 presents production parameters and offtake rates of goat flocks. Offtakes include the number of goats sold, given as gifts, consumed and deaths. Two thirds of the offspring left the flock. In general, all the males are sold when does are still lactating. There were no significant differences between the two areas with the exception of goats given as gifts and goats eaten, which were higher in Michoacán. A popular dish is made of goat kids meat known as 'birria', which is sold in the nearest town of la Barca and in Guadalajara metropolitan area. Goat kids are bought at the farm gate by a trader for about 260 MX$ in 2009. Farmers try to keep their female goat offspring for replacement and for increasing their flock size. Farmers use the male offspring also for home consumption and for gifts or payments in kind, the latter being important to access grazing crop residues.

GOAT HEALTH CARE

Table 5.5 shows the annual goat health related expenses farmers made. Health care inputs are very similar for both states except that Michoacán farmers spent significantly more on minerals than Jalisco farmers. During the field observations we noticed that in general farmers buy goat health inputs in veterinary shops where they also get advice on what to buy and how to apply it. Prescriptions are given based on goats' clinical signs reported to the veterinarian by the farmer. Veterinary shops are in towns and cities at a distance of 10 to 20 km from the villages. In general, veterinarians do not visit the goat pens. An exception is when farmers are involved in a subsidized extension GGAVATT group. The veterinarian assigned to a GGAVATT will then do clinical inspections on goats.

GGAVATT's groups were relatively new for farmers of Michoacán and started at the climax of brucellosis vaccination campaign conducted by CM. From an interview with a coordinator of the GGAVATT's we learned that 70 groups existed in the whole state of Michoacán,

Table 5.4: Comparison of production and offtakes between flocks of the states of Michoacán and Jalisco, Mexico

	Michoacán (n = 25)		Jalisco (n = 21)	
	mean (%)	SD (%)	mean (%)	SD (%)
abortions	23.6	23.9	21.1	15.3
death does	5.9	7.7	8.1	13.5
death kids	8.3	10.3	13.7	12.5
consumed goats*	5.6	4.2	3.3	3.0
gifts*	8.6	7.7	3.5	3.4
offtake does	34.5	59.6	21.7	15.6
offtake kids	65.1	25.3	66.9	25.3

* Denotes significant difference between means of the two states (t-test, $P < 0.05$)

of which 19 were in the study region. Of those 19, 16 focussed on cattle and 3 on goats. The goal of the GGAVATT group is that farmers adopt technologies, such as the use of veterinary drugs including brucellosis vaccine and the adoption of milking machines. The GGAVATT veterinarian had a low esteem of a goat farmer's knowledge of goat health care and a farmer's behaviour towards adoption of technologies.

> "... they are very traditional, they resist changes, for example we have built milking ramps, if we leave them alone, they will stop using them...farmers do not know how to prevent diseases. Our aim is that the farmer knows the vaccines. A veterinarian knows that [vaccines] work because they are scientifically tested. A goat farmer does not know, they need to know, to test and then to adopt...(Gilberto Montes [pseudonym] GAAVAT coordinator)"

In Jalisco villages no GGAVATT groups were found.

FARMERS' OPINIONS ABOUT CONSTRAINTS FOR DEVELOPMENT AND BRUCELLOSIS

During in-depth interviews farmers reported low milk price, lack of a good pen, feed costs, crop residues lessening, droughts and goat diseases as the main constraints. This was confirmed by the survey outputs in Michoacán (Figure 5.3) and by the group discussions. Milk price was on the stage in all the discussions and was ranked as the most important issue for farmers. Although there was a general consensus about the main problems some opinions were debated among farmers. For example,

> "what is the point of a better milk price if our goats are not healthy, because if our goats are not healthy there is no milk, then the milk price is not relevant, (goat farmer, Barranca el Aguacate)"

The main diseases affecting goat flocks ranked by farmers in Michoacán were pneumonia, abortion, mastitis and diarrhoea (Figure 5.4). During the group discussions farmers also

Table 5.5: Comparison of inputs[a] for goat health care between flocks of Michoacán and Jalisco, Mexico

	Michoacán (n = 25)		Jalisco (n = 21)	
	mean	SD	mean	SD
minerals[*]	17.1	14.4	10.7	10.9
antibiotics	13.3	17.7	16.8	14.2
dewormer	11.3	7.9	13.5	9.1
vitamins	7.1	7.1	9.0	9.2
vaccines	2.1	2.3	2.6	4.0

[*] Denotes significant difference between means of the two states ($P < 0.010$)

[a] Mexican pesos (MX$) y^{-1} per goat

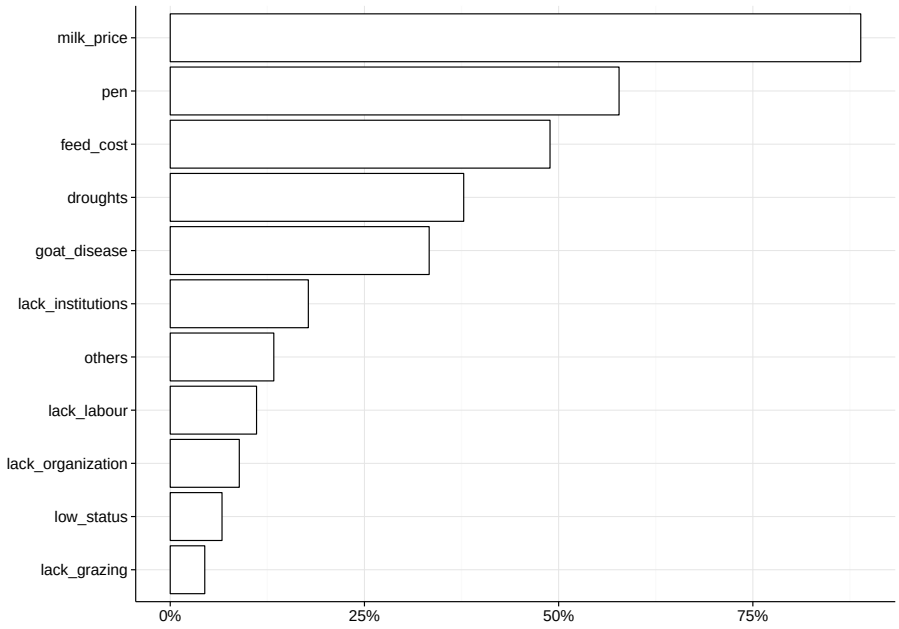

Figure 5.3: Constraints to small-scale goat husbandry development according to farmers of Michoacán (n = 45)

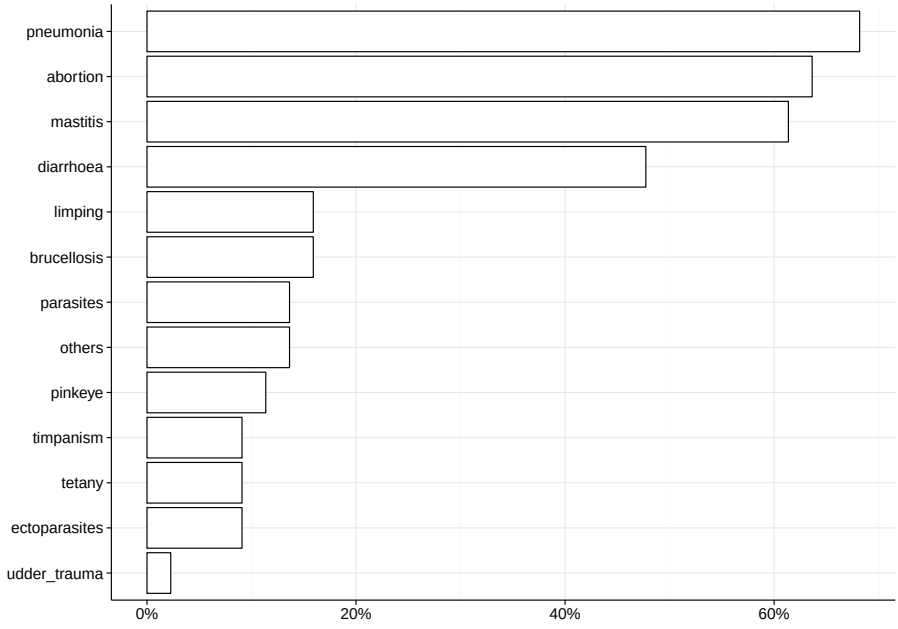

Figure 5.4: Most common diseases in goat flocks according to farmers of Michoacán (n = 44)

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ranked these diseases as the most important although not exactly in the same order. Pneumonia and diarrhoea cause deaths especially in young goats (< 1-year-old), mastitis leads to reduced milk production. Added to this, goats recovered from mastitis but without a full functioning udder have to be sold for a reduced price. Abortions have a direct impact on the flock fertility and for farmers this means less goat kids and less milk production.

Although brucellosis may cause abortion, during some workshops and interviews brucellosis was not even mentioned. In one village of Michoacán brucellosis was ranked as the most important disease. A farmer from this village said during an interview they were planning to work together with CM to produce yoghurt made of goat milk. One farmer from another Michoacán village said in regard to brucellosis in goat flocks:

> "...with regards to brucellosis, it is important indeed, because if the company asked us about goat milk without brucellosis what are we going to do? (goat farmer, Michoacán)"

KNOWLEDGE OF BRUCELLOSIS

The term 'brucellosis' was difficult to pronounce by farmers from both states. "This disease..mmhh, how do you say is called?"(goat farmer from Jalisco, who himself had brucellosis < 3 years ago). Another farmer stated:

> "I had brucellosis 45 years ago...I did not know the name of that disease, we started hearing about it when the *'cajeta'* industry came here. Even before the veterinarians came. He [the veterinarian] was saying brucellosis... And I said: that damn disease you must have brought it from elsewhere (Noé Torres, [pseudonym] senior farmer from Michoacán)".

Farmers knew brucellosis better as *'la fiebre malta'* (Malta fever). Figure 5.5 shows farmers' knowledge about some aspects of brucellosis gathered through a survey. Significantly more farmers from Michoacán (∼70%) knew about the existence of a brucellosis campaign than farmers from Jalisco (20%, χ^2 p-value < 0.005). The most known fact about brucellosis was that it can be transmitted to humans. Knowing that brucellosis can be transmitted to goats and mentioning symptoms of brucellosis in humans were relatively well-known aspects. Fever was the brucellosis symptom farmers often recognized in humans. Relatively few farmers (∼30%) knew that goats can transmit brucellosis to other livestock species and few could identify that other livestock can be carriers of brucellosis. The most unknown aspect among farmers concerned the clinical signs of brucellosis in goats.

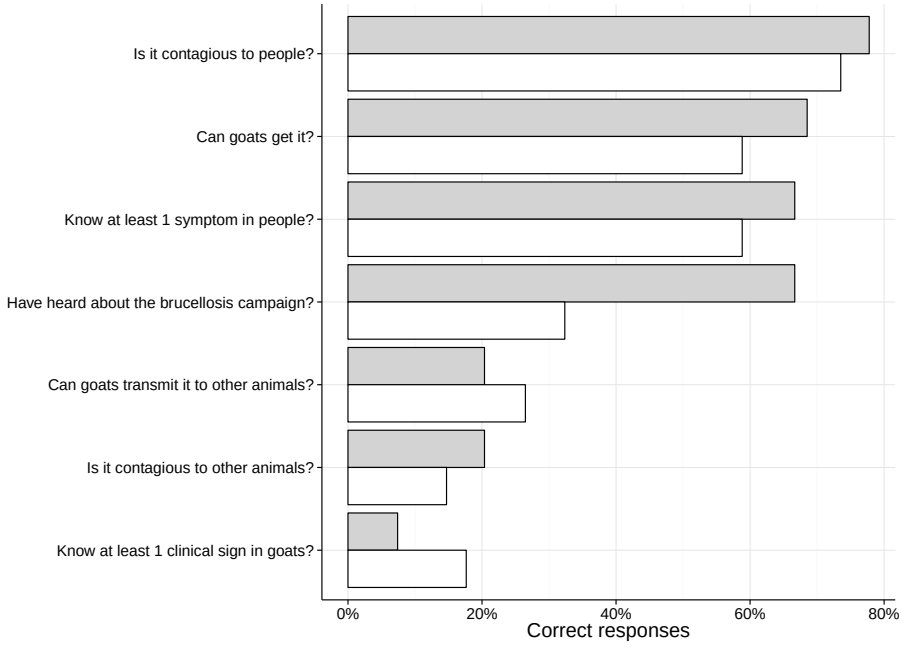

Figure 5.5: Farmers' knowledge about some aspects of brucellosis. Grey bars farmers from Michoacán (n = 54) and white bars farmers from Jalisco (n = 34)

Farmers' struggles to recognize brucellosis in goats through clinical signs was cross checked with other health problems in goats in focus group discussions. Farmers were able to point

out several diseases that affect goat flocks such as pneumonia, diarrhoea, mange, mastitis, arthritis and foot rot among others. But brucellosis was not mentioned or pointed out as a health disorder in goats. They were asked about it and farmers responded that brucellosis was not visible and they did not know about it. Moreover the disease was not fatal in goats whereas other goat diseases were fatal. Farmers knew that drinking raw goat's milk, caused them fever.

> " ...as I tell you, now, we do not even taste it [goat milk]. I used to drink up to 3 litres of milk daily, I used to take sufficient tortillas and bread and I had a red-face from so much milk, but I got the fever (goat farmer, Michoacán)"

> "...I got the fever about five years ago, and only because of the 'odour' [respiratory route] I did not drink milk. But not long ago I had the fever again, we began to milk the goats early and he [farmer's son] told me, you do not want milk? I said no, I do not want goat milk. Then he took a glass and he drank a glass of milk, then I said okay, let's try it. And then the ailment started and I went to my cousin in the town, who has a lab, and I was diagnosed to have brucellosis (goat farmer, Michoacán)."

EXPERIENCES WITH VACCINATION

In Michoacán vaccination of goats had a relatively good coverage due to the way the CM committee organized it. CM decided to carry out the vaccination campaign even if a farmer did not contribute financially.

> "...look there are two truths here, in our case at the beginning we asked farmers to cooperate [financially]. They hardly did it, they gave 1,2 or 5 pesos, and only some of them, but in the last years they did not even give 5 ¢. I understand that if a committee reports that farmers do not cooperate, then the funds are cut...to the outside world you say yes they paid their share. But the reality is different.....for farmers in this country it is not clear why they should vaccinate against a damn thing [brucellosis] that they never heard about and suddenly someone shows up and says that you should vaccinate. Because they have 40 or 50 years with their goats -with brucellosis- but they are still in business... then [governmental] planners have two options, [1] they either go back to their office in Mexico City and continue to philosophize about brucellosis or [2] they stop charging 7 or 5 pesos [for vaccine] to the farmer and you control brucellosis. And we opted for the second option". (committee member)

Next to costs, vaccination had other downsides for farmers. During the control campaign in one the villages of Jalisco (San Vicente or Labor Vieja) farmers were approached by a veterinarian who offered to vaccinate their goats. Four out of eleven farmers accepted to vaccinate their goats at a cost of 10 MX$ per head. They were promised to get their 50% refund by the municipality, as it should be in theory, the municipality taking part in the costs as dictated by the policy. However, farmers reported that obtaining funds from the municipality for having their goats vaccinated against brucellosis was bureaucratic. The office they had to go to for reimbursement was about 11 km away from their village. Two farmers went twice to the municipality but they did not get any refund. They did not try any further because the costs outweighed the promised refund. "They would have told us, the

cost is 10 pesos per head and that's it. Now we have lost more due to the transport to get there and due to hiring a herder during the visits to the municipality" (Dante Aguirre [pseudonym] goat farmer). Other farmers who did not take the offer of the veterinarian expressed their disappointments. First, they said that it was unfair that the cost for vaccination against brucellosis was equal regardless the size of the livestock species, goat or cow. Second, they thought that the veterinarian was making a lot of money in a short visit for vaccinating the goats, the money the veterinarian was earning for each flock vaccinated was comparable in some cases to the income obtained in a week by selling milk.

Abortion due to vaccination brought additional losses. Farmers from Labor Vieja who had vaccinated their goats reported that their goats aborted more often due to the vaccination. The vaccine was applied at the end of the breeding season when most goats are pregnant. Another problem was the identification system by ear tags, despite being relatively small, they were not suitable for the extensive grazing systems. Ears got easily damaged during browsing when goats got trapped and tried to escape which may result in serious ear infections.

EXPERIENCES WITH TESTING AND CULLING

Testing of flocks whether or not they are positive to brucellosis has been performed less systematic than vaccination. In Michoacán about 5,000 goats were tested in 2004, whereas in Jalisco state testing was negligible. Two examples, first, the village San Vicente/Labor Vieja where farmers reported that testing took place once in the year 2000. Second, the village of Barranca el Aguacate where farmers reported that they had not been asked to test their flocks. In Michoacán a higher percentage of flocks were tested (61%) than in Jalisco (25%, χ^2 p-value < 0.001), and 85% (35/41) of those flocks had at least one positive goat. On average, 7 goats were tested positive in flocks of both states (Table 5.6). About half of the farmers sold their seropositive goats. Prioritizing other issues and diseases over brucellosis and not culling their seropositive goats had to do with noticing that goats testing positive to brucellosis were nonetheless good milking goats. To farmers, a good goat yields at least 2 litres of milk per day in the peak season. So selling a 'good' goat, but positive to brucellosis, was a considerable loss. The trader would pay farmers 800 MX$ per goat, but if farmers wanted to buy a replacement milking goat this would cost about two times this price.

Table 5.7 shows the interfaces of brucellosis control policy with the goals of goat husbandry of the Bajío region. The core of the policy is based on vaccination with Rev 1 vaccine, test-and-culling. Farmers reported various disadvantages with regard to vaccination, which made it unpopular among farmers. Despite this farmers have vaccinated their animals when the service was for free and in Jalisco some farmers adopted the vaccination despite the costs and losses due to abortion. With regards to test-and-cull, farmers also reported the incoherence of the policy and how the traders will keep spreading the disease even if farmers made an effort to control it.

Table 5.6: Comparison of brucellosis control activities carried out in flocks of the states of Michoacán and Jalisco

	State	
	Michoacán N(%)	Jalisco N(%)
Flocks tested[*]		
Yes	33 (61)	8 (24)
No	21 (39)	26 (76)
Flocks tested positive		
Yes	27 (82)	8 (100)
No	6 (18)	0 (0)
Farmers that sold positive goats		
Yes	11 (40)	6(75)
No	16 (60)	2(25)
Seropositive goats	Mean (IQ)[a]	Mean (IQ)
	7 (3-8)	7 (5-7)

[*] $\chi^2 = 10$, df = 1, p-value < 0.001

[a] First and third interquartiles

Source: Authors cross-sectional survey in Michoacán and Jalisco 2008

Table 5.7: Interfaces of brucellosis control policy and farmers perceptions

Policy/activity theme	Issues	Illustrative quotations from farmers
Vaccination	Cost	"Can you imagine, 10 MX$ per head?...
	Causes abortion	You have vaccinated your goats for almost 6 years, have you noticed a difference? "yes, they abort more"
	Ear tags not browsing proof	"goats will not be tagged right?, goats are screwed up with the ear tags"
	Contacts with other flocks/herds	"The vaccination has to be even otherwise what is the point"
	Unclear why to vaccinate	"here, nobody has explained us about brucellosis, the campaign"
Test-and-cull	Goat milk income source	"Can you imagine, if we sell our goats what milk we are going to sell?"
	Seropositive goats are 'good' milk producers	"look, goats marked as brucella positive are good goats"
	Trader resells seropositive goats	What did you do with your positive goats? " we sold them [24 goats] to the trader, but the trader resold them to another guy here in the next village"
	Organization	"We all have to agree on it, we should agree on a notch in the ear of goats with brucella, so the trader does not sell that goat to the next farmer"
Human brucellosis	Not easy to cure	"The medicine did not have an effect, because I was bewitched, until I was free from the hex, the medicine made effect","what sent me backwards was the disease [the brucellosis]"
	Knowledge of cause, experience dreadful symptoms	"I sweated like a cow piss" "I thought that I was dying" "it is due to the goat milk"
	Experience sequelae	"I do not have strength in the hand to milk", "I can't lift grain sacks any more [40 kg]"

5.6 DISCUSSION

Goat farmers in the Bajío region, Mexico, are often confronted with brucellosis control policies that appear paradoxical in regard to their frame of reference. Farmers are required by law to cull goats positive to brucellosis, which they perceive as 'good' dairy goats. This is not surprising given that brucellosis is not easily recognised. In the 1900's, it was believed that goats were not carriers of brucellosis, because goats did not become ill when they were inoculated with *Brucella* cultures (Nicoletti, 2002). Infected goats can abort, but subsequent pregnancies can be normal (Corbel, 2006). Farmers, therefore, accept an abortion per goat during the lifespan of a goat. Furthermore, abortion is not a unique pathognomonic clinical sign of brucellosis. Abortion can be caused by *Chlamydia, Leptospira, Coxiella burnetii, Toxoplasma, Listeria* (Nietfield, 2013), and by other factors such as malnourishment and traumas. In practice, financial compensation for culling seropositive goats does not exist. This can explain why in Michoacán, the state where an intensive vaccination programme has taken place from 1999 to 2006, 60% of the farmers did not sell their goats that tested positive to brucellosis. Furthermore, disposal/trade of infected animals is neither well organised nor supported. Farmers who did sell their seropositve goats found it ironic that the trader resold their goats to neighbours.

In general, the goat husbandry system in the villages of both states is similar in management and objectives, i.e. extensive grazing, dairy production, flock sizes and structure and health care. Brucellosis control, however, in goats has been promoted more in Michoacán than in Jalisco, resulting in a lower prevalence: 12% versus 38% respectively (Oseguera Montiel et al., 2013). The main control activity in Michoacán was vaccination and the uptake was $\geq$ 90% in the villages visited. Vaccination against brucellosis was offered for free to farmers. In contrast, in Jalisco vaccination activities were dependent on private veterinarians and cost $\sim$ 10MX$. This suggests that brucellosis vaccination will be adopted massively when it is offered for free to farmers or when the vaccine against brucellosis equals the costs of vaccines against other diseases. When this study was conducted the price of having a goat vaccinated against brucellosis was 9 times higher than having a goat vaccinated against *Clostridium* spp. and *Mannheimia haemolytica*. Farmers are skillful in injecting goats. Handling Rev 1 vaccine however, requires special care as accidental self inoculation while injecting goats is a risk. A veterinarian conducting the campaign in Michoacán said that he acquired brucellosis in this way.

One would expect that the intense vaccination campaign would have had a good impact on production parameters, i.e. reduced abortion rate, higher milk production. We found, however, that the brucellosis campaign had unpredicted consequences for farmers, i.e., abortions and ear infections due to ear tagging with consequences for milk production. With regard to abortion, a farmer who has been vaccinating his goats for six years said that vaccination against brucellosis has caused more abortion. Farmers in Jalisco reported also that a veterinarian exhibited unprofessional conduct as he vaccinated four flocks when goats were pregnant. These farmers noticed a higher abortion rate after having their goats vaccinated than in previous years. Rev 1 vaccine should be used in goats that are not pregnant (Blasco, 1997) and the policy in Mexico is explicit on this too (SAGARPA, 1996). Vaccination when goats are not pregnant can be done only if veterinarians and committee's personnel are knowledgeable about goat husbandry practices, e.g. seasonal breeding of flocks, and when

they work together with farmers in designing an identification system for goats that fits with extensive grazing system. A modelling approach showed that vaccination with Rev 1 against brucellosis in goats is economically profitable (Oseguera Montiel et al., 2014b), but the abortions due to vaccination – a negative consequence to farmers – needs to be prevented. A reduction in the seroprevalence of brucellosis due to vaccination was not associated with a significant reduction in the abortions in flocks in the villages of Michoacán when compared to flocks in the villages of Jalisco. Abortion can be reduced when the prevalence of brucellosis drops, but most likely the vaccination of pregnant goats could not be fully avoided in Michoacán, which could raise abortion rates.

The Mexican law for brucellosis control and eradication states that there should be a continuous campaign promotion. More farmers from Michoacán knew about the campaign than farmers from Jalisco, however the most striking thing about the brucellosis (newest) policy dated in 1996 is that farmers from both states have limited knowledge about brucellosis and with almost no difference between the two areas. This suggests that the promotion of the campaign is not working properly. The most known fact about brucellosis by farmers is that it is contagious to humans. This was also found in Portugal among cattle farmers (Díez and Coelho, 2013). Farmers have learned that drinking raw goat milk can cause fever–'*La fiebre Malta*'. This knowledge explains why only about half of the households keeping goats in the area do use their own goat milk and destine it to make cheese or *'cajeta'* (milk caramel) (Oseguera Montiel et al., 2014a).

Drinking goat's milk is not recommended by physicians in the area. But caprine brucellosis and –'*La fiebre Malta*' was to some extent disconnected in farmers views. Not everybody knows that both are caused by the same pathogen. Furthermore, farmers are still at risk of being infected with *Brucella* through other ways by being in frequent contact with goats, e.g. milking, eating goat and cow cheese from unpasteurized milk. The fate of farmers infected with brucellosis is like flipping a coin. There were farmers who were diagnosed relatively quickly, but there were farmers who said that they felt like dying because lack of prompt and correct diagnosis and treatment. This means that physicians are not fully aware about human brucellosis and the high prevalence in the goat population, which is $\sim$ 20% (Oseguera Montiel et al., 2013). Such experiences provoke farmers to believe in sorcery. A farmer who suffered brucellosis for five months believed that drugs did not cure him because of sorcery, most likely the farmer was not diagnosed *Brucella* positive at the outset of the first symptoms. Farmers often carry a radio while herding. However, mass communication through radio programmes aiming to inform farmers (and physicians) about brucellosis has not been used in the region. This could be an efficient way to divulge scientific knowledge of brucellosis.

There are not many secrets in the control of brucellosis, the recipe, vaccination for control to lower first brucellosis prevalence and the subsequent adoption of test-and-cull goats is discussed in number of papers (Minas, 2006; Blasco, 2010). This is in general, the way that brucellosis has been eradicated in the Western European countries. Sonora is a state in north Mexico where brucellosis is on the way to eradication. The application of the brucellosis control measures has been rigorous. The key driver in Sonora state, is the export market of cattle to the US. In the study region however, goat farmers and the government do not have yet a market driver that sparks the adoption of brucellosis control measures; the main milk commodity is *cajeta*. Two roads are ahead: 1) the industry processing goat milk supports farmers to eradicate brucellosis or 2) farmers find a niche market for a high quality dairy

milk product. CM attempted this and their farmers were more interested in controlling brucellosis because they could see an economic benefit.

One of the striking findings is how the brucellosis campaign efforts are not connected in the two bordering states sharing the same agroecological conditions. Trading of animals is common between the two states. *Brucella* spp. goat carriers can be moved easily from one state to the other due to trading, but also by transhumance. The efforts of brucellosis control in goats with cattle are also disconnected. In Michoacán the intense campaign to control brucellosis in goats was not paralleled by control of actions in cattle. An integral regional approach will be needed. Such an approach needs to understand the farmer's frame of reference – this is made up of their beliefs, knowledge, experiences, interests and practices– and focusing on regions that can go beyond administrative borders. Culling seropositive and vaccinating goats will be adopted faster if farmers get full compensation for their loss as is the case in European countries, such as Spain (DGSAPA, 2013). Brucellosis control is a political issue, farmers, dairy industry, animal health and human health authorities must work together to succeed (Sriranganathan et al., 2009), as proposed by the 'One Health' concept (Zinsstag et al., 2005).

In order to implement this 'One health' concept local stakeholders could be involved more actively, such as the village physicians, who can be trained and equipped to run serological tests in humans. During field work, farmers, who had symptoms suggesting brucellosis infection, were encouraged to be tested against brucellosis. Four farmers were sampled by the local physician, but the results were never returned to the farmers. Furthermore, to reduce costs for the brucellosis control measures in goats, women could be trained not only to vaccinate goats against brucellosis with Rev 1, but also to run serological tests such as the Rose Bengal Test, which is relatively simple to conduct under field conditions.

5.7 CONCLUSION

The brucellosis control campaign in Mexico shows a slow pace towards eradication. The current top-down driven brucellosis control policy in Mexico is intermingled with a range of socioeconomic factors which results in a weak compliance with the brucellosis control policy. There is a two way lack of communication: farmers know little about brucellosis and policy makers and veterinarians know little about small-scale goat husbandry management and the farmers' frame of reference and sometimes resort to unprofessional conduct vaccinating pregnant goats. Farmers have shown willingness to control brucellosis, but they need to be informed and supported, receive compensation for culled seropositive animals and vaccination for free or at least at comparable prices with other vaccines. These will need to be paralleled with an effective organization of slaughtering seropositive goats, vaccination when goats are not pregnant, an identification system that fits with extensive grazing, control of brucellosis in cattle and a regional approach that goes beyond the administrative borders. While brucellosis remains uncontrolled, farmers are exposed to the pathogen and the consequences that brucellosis has on farmers' livelihoods are serious. The 'One Health' approach to control brucellosis may have simultaneous benefits for both goat and human health and may help to promote understanding of brucellosis among farmers and the need for its eradication.

6

GENERAL DISCUSSION AND CONCLUSIONS

6.1 INTRODUCTION

Brucellosis is the most common zoonosis in the world (Pappas et al., 2006) and has a negative impact on livestock production (Corbel, 2006). Therefore, much research has been done to combat the disease, but despite the wealth of knowledge, including tools like vaccines and serological tests, brucellosis remains endemic in Mexico and in many other countries of the global South (OIE, 2013). There is no vaccine to protect humans from brucellosis and the occurrence of brucellosis in livestock is related to human brucellosis (Godfroid et al., 2005). Therefore eradication of *Brucella* from animals especially the biovar *B. melitensis*, transmitted from goats and the most virulent in humans, should have a priority in animal disease prevention. The objectives of this thesis were to assess the impact of brucellosis on smallholder goat husbandry and to evaluate brucellosis control strategies in the Bajío region, Mexico.

Goat husbandry has been depicted as a pathway out of poverty (Devendra and Chantalakhana, 2002; Lebbie, 2004; Peacock, 2005). However, as Peacock also pointed out there are many obstacles for goat husbandry development. Is brucellosis one of these obstacles? And if so, how can it be controlled in an environment where other obstacles for development are also present? The methodological backbone underlying this thesis is the DEED framework, an acronym for 'Describe', 'Explain', 'Explore' and 'Design', which was developed as a research cycle for studies assessing natural resource management (Giller et al., 2008). First, Chapter 1 **describes** the historical background of goat husbandry and the current situation of brucellosis in Mexico, which is still endemic in domestic livestock and affects humans too. Chapter 2 is based on livelihoods approaches (DFID, 1999; Ellis, 2000), and **describes** farmers' livelihoods in the context of social, and economic and ecological drivers, e.g. migration, neoliberal policies and terrestrial resources. Goat husbandry is dairy oriented; it is a source of weekly income, insurance, and a reason for not having to migrate to the US. Farmers' social capital allows them to access cheap crop residues and take turns for herding flocks. The goat dairy market is controlled by the caramel industry and the margins farmers obtain are rather limited. Also, the nutritional value of goat milk is not exploited in farmer's own households as it is seen as a cause of 'fever' which is due to brucellosis.

The research approach followed is that of a case study. One of the strengths of a case study is its flexibility in the design and in the combination of qualitative and quantitative methods (Yin, 2009; Becker et al., 2012). One example of design flexibility is that at the beginning of this research only villages of Michoacán were included, because brucellosis was an issue addressed by a non-governmental association. The association had been active in conducting

brucellosis vaccination and testing in goats of Michoacán in a highly comprehensive way and exceptional in the country. Once in the field, it was recognized that farmers in the bordering state of Jalisco were not aware of the national goat brucellosis control campaign. In Jalisco, control strategies had not been implemented extensively. Therefore, the study was extended to Jalisco as this was seen as an opportunity to compare the brucellosis status in the goat population in both states. Chapter 3 **explains** the seroprevalence and the risks factors of brucellosis. The serological survey showed that the prevalence of testing positive to brucellosis was higher (38%) in Jalisco, than in Michoacán (11%), being a major result of the higher vaccination coverage in Michoacán.

Another strength of a case study design is that emphasis is put on the context, which helps to bridge a gap between abstract research and practice (Becker et al., 2012). In this study veterinary epidemiology and animal health economics outputs were put into context to assess the feasibility of control strategies. In Chapter 4 control strategies are **explored** based on a series of models related to: epidemiology, flock growth and economics. Scenarios consisting of test-and-cull or vaccination or a combination of both were compared to the base situation without active control. A brucellosis control campaign based on vaccination with full coverage is economically profitable for the goat dairy sector of the region. However, if test-and-cull is applied, to reduce the prevalence more quickly and to lower levels, the economic outcomes turn negative, and smallholders cannot bear these costs on their own.

In Chapter 5, exploration of solutions is taken one step further by incorporating farmers' perceptions, that influence the adoption of brucellosis control strategies. Farmers' perspectives were assessed through ethnographic methods. In Chapter 5 the idea is disputed that brucellosis is confined solely the lack of awareness and lack of participation of farmers in control measures, but also control policies are designed and implemented without a good knowledge of goat husbandry and farmers' perceptions. In this General Discussion, the DEED research cycle is closed by presenting a re-**design** of the brucellosis control campaign in the study area, and elaborating on the future of goat husbandry in the Bajío region, Mexico.

6.2 A CHOICE FOR GOATS: RESILIENCE OR VULNERABILITY?

Goat husbandry has become a popular activity among smallholder farmers in the study site. For example, in one of the villages farmers referred that the number of farmers has increased 7-fold since the early 1990's when the caramel industry started to operate in the area (Chapter 2). This is in contrast to the national trend in which the number of goat farmers has declined by 40% between 1991 and 2007 (INEGI, 1991, 2007). There are various reasons for the growing interest in goat husbandry in the study site.

1. The price paid to farmers for maize, the main crop cultivated, has more than halved between 1990 and 2005 (Fox and Haight, 2010) as shown in Figure 6.1. In response to this, some farmers opted to reinvest their crops as feed in goat husbandry (Chapter 2), thus goat husbandry has contributed to farmers' resilience.
2. Another factor is the abundance of natural capital, communal land with shrub vegetation and residues of the crop land. These are important feed sources for goats (Chapter 2). This allows goat farmers of lower strata, with little land or landless farmers to own goats (Chapter 2). However, with the termination of the *Ejido* land tenure

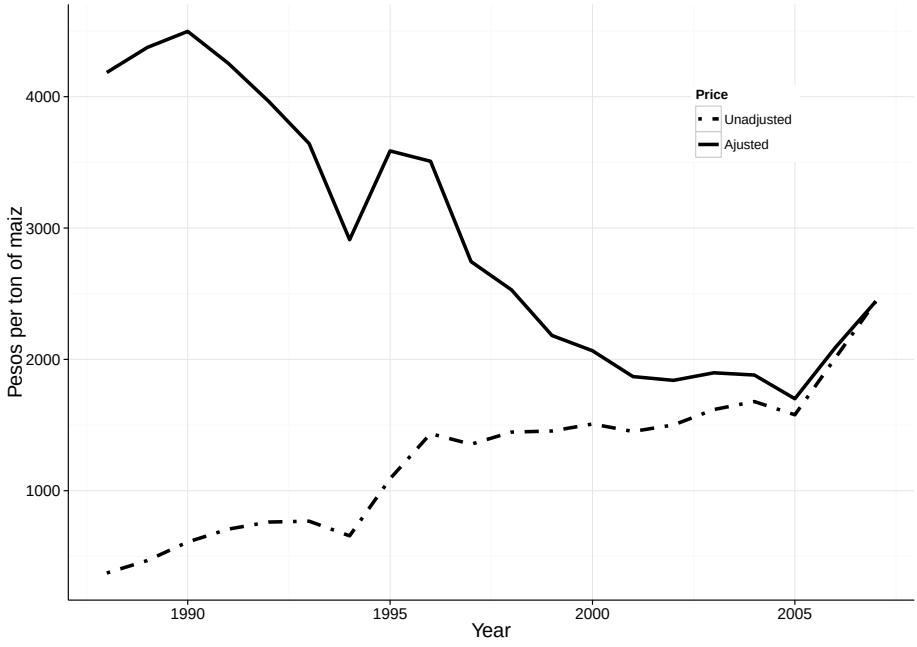

Figure 6.1: Farm-gate maize price per ton paid to farmers adjusted and unadjusted to prices of 2007. Data source: (SIAP, 2014)

system, a result of the Mexican revolution, communal land became marketable. This has put pressure on land use which is threatening pastoral goat husbandry. As an example, a feedlot industry started operations in 2006, having a negative impact on the environment according to farmers of los Charcos village because of air and water pollution. The feedlot received substantial support from the government – 203 ha of crop land for free (Extra, 2013).

3. The growing demand for goat milk by the caramel industry also attracted crop farmers to start keeping goats (Reséndiz Torres, 1999). The dairy goat market existed already for a long time in the study region, but the demand for goat milk increased when caramel companies set up processing plants in the region. One company, Coronado, was bought by a multinational, which anticipated market opportunities in the US due to the NAFTA agreement (Reséndiz Torres, 1999). Farmers obtain a weekly income by selling their raw milk to the caramel industry and therefore goat husbandry contributes to their resilience. In contrast, if farmers sell maize, they have only one cropping cycle because most farmers have rain-fed land.

4. The growing interest in goat husbandry is also due to lack of employment for farmers. In Mexico agricultural employment dropped sharply between 1991 and 2007 from 10.7 million to 8.6 (INEGI, 1991, 2007). According to farmers, agricultural off-farm job

> opportunities within the region are scant and not attractive enough; jobs are temporal, not well paid and risky, when the job is related to working with chemicals, e.g. pesticides and herbicides (Chapter 2).

Farmers consider it is 'better to herd than be herded', which means that they prefer to be their own boss, enjoying more independence, and securing an income regardless whether they are hired or not (Chapter 2). The neoliberal era has caused a deep transformation not only in Mexico but in the whole world. Unable to compete with industrial farming systems of the global North, smallholder farmers struggle to make a decent living based only on agriculture (Rubio, 2006). Goat farming has become part of a broad range of activities that farmers combine, like cropping, temporal migration, off-farm jobs, and keeping other livestock, such as pigs and cattle. A wider range in the activities is associated with a better socioeconomic position with an improved livelihood (Chapter 2). The diversification of activities is known as the 'new rurality' in Latin America, which stresses rural transformations as a consequence of globalization (Kay, 2008). Diversification, furthermore, is one of the ways in which smallholder farming persists according to peasantists (Kay, 2008; van der Ploeg, 2010). The exodus of Mexicans to the US is unprecedented, however migration is riskier than even before, not only for Mexican farmers but also for Central American citizens (Izcara-Palacios, 2012) who are vulnerable and easy prey for criminals and drug smugglers. Furthermore, returning home has become more complicated because border surveillance is tougher. International migration provides households with remittances that are invested in inputs for goat husbandry (e.g. feed and goats) (Chapter 2).

In this thesis the sustainable livelihoods framework (Chambers and Conway, 1992; DFID, 1999; de Haan, 2000; Ellis, 2000), here referred to as the livelihoods framework, was used to understand goat husbandry as part of farmers' portfolio of activities for sustaining their livelihoods. The livelihoods framework offers a systematic way of looking at various aspects of the livelihoods, particularly through the voices of poor people (Ashley and Carney, 1999; DFID, 1999). Figure 6.2 resumes the flows of inputs in a goat farm. Flows are based on the so-called capitals of the livelihoods framework: physical, natural, social, and financial. Here goats, which are a natural capital in itself, are used to generate an income through meat and milk production so they are also physical and financial capital. For farmers goats are liquid cash, goats are sold in case of emergencies and are a warrant to obtain credits.

Goat meat and goat dairy products, e.g. cheese, are consumed at home. Analysis of livestock production in smallholder farming systems is too narrow if it is based on physical production only (financial capital and milk and meat production) (Udo and Cornelissen, 1998). There are other functions that farmers appreciate in their goats: goat keeping is valued as a job source and apprenticeship for children, farmers can provide a *'Birria'* (a popular goat meat dish) for family reunions; goat kids are given as gifts to strengthen relations with neighbours (social capital), and goats are a means to support children to become independent, i.e. forming their own family (Chapter 2).

Figure 6.2 gives, however, an idyllic view of goat husbandry for various reasons. First, whilst goat meat and goat cheese are consumed at home, drinking milk is not a custom and farmers perceive milk consumption as a risk of 'fever', referring to Malta fever (brucellosis). The disease is widely spread in the goat population in the study region as 71% of the flocks had at least one *Brucella* seropositive goat (Chapter 3). Brucellosis does not only have a negative impact on goat production but also threatens farmers' health and thus affects hu-

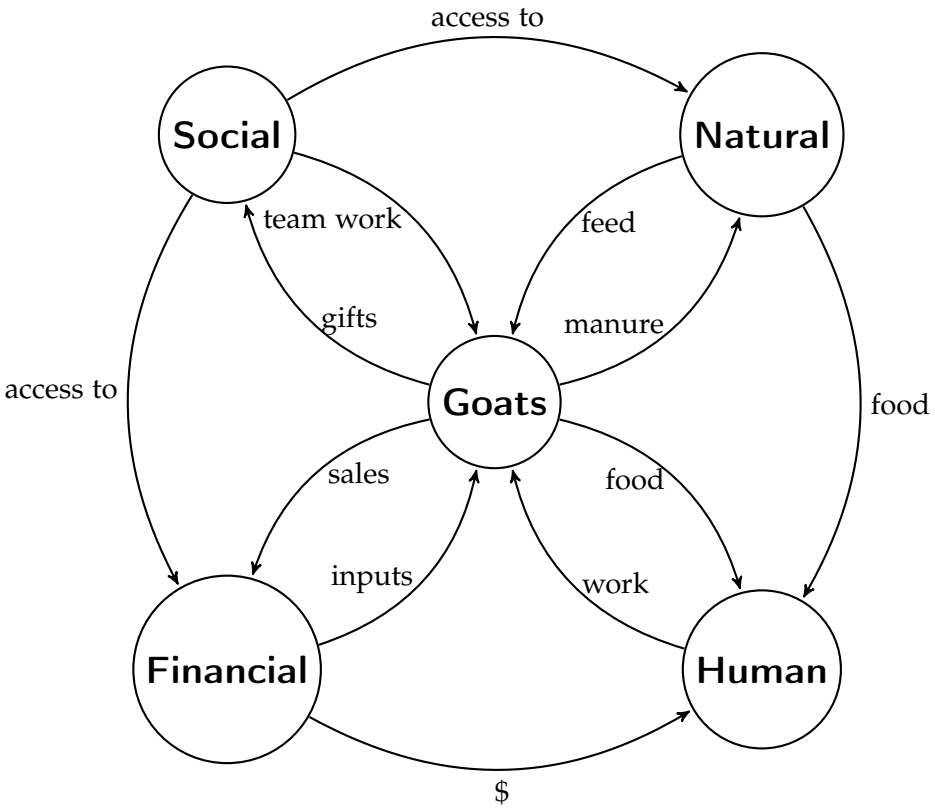

Figure 6.2: Goat husbandry: contribution to livelihood capitals

man capital (Chapter 2). Added to this, farmers who get infected are not promptly treated (Chapter 5). All of which make farmers' livelihoods less secure.

Second, farmers' goat flocks have an important social function that has a positive impact on human capital. Farmers reported that their children learn about goat keeping and it keeps them busy so they do not run into trouble (Chapter 2). Teenagers help in goat management during school holidays, weekends and even take the lead during the absence of their father due to off-farm jobs or migration to the US. But there are two downsides here, one is that teenagers drop out of school easily by having the excuse of helping their family taking care of the flock, and it also puts them at risk of human brucellosis due to the close contact with the goats (Figure 6.3).

Third, goat husbandry management in the study site can be described as a pastoral system for most flocks (Chapter 2). Such a system, based on sedentary and semi-transhumant grazing is a cheaper way to maintain dairy flocks in the region compared to stall-fed systems, because feeding costs are lower (Chapter 2). However, in stall-fed systems the probability of goats being *Brucella* seropositive is far lower (OR = 0.22) than for goats kept in a pastoral

Figure 6.3: A young farmer in his teens milking a flock, his father was in the US

system (Chapter 3). This is a great disadvantage because it means that farmers keeping goats in a pastoral system are more exposed and more likely to become infected. Most likely the higher odds of being seropositive when grazing is caused by the direct and indirect contact with neighbour flocks and cattle herds sharing grazing areas (Figure 6.4).

Fourth, the dairy market does not offer a satisfactory milk price (Chapter 2). To farmers the price is stagnant and living costs increase as well as the costs of inputs, such as feed (Chapter 2). Only farmers with relatively large flocks, $>$ 30 goats/per capita, and over 4 ha of crop land per household have returns from goat husbandry and cropping, which puts them close to or just above the poverty line, set at US$ 3.8 per day in rural Mexico by CONEVAL (2010).

One of the criticisms of the livelihoods approach is that politics are often not included in the assessments (Scoones, 2009), here specifically this refers to power relations, which determine access to resources (capitals) and to livelihood opportunities for the poor (de Haan and Zoomers, 2005). In this thesis, therefore, special attention is paid to these. In Chapter 2, it is stated that the benefits of smallholder goat husbandry in the study region are affected due to the power of the caramel industry of the region, which controls the goat milk market. One of the caramel companies is a subsidiary of the fourth largest food industry in the world (Ochoa, 2013), what van der Ploeg (2010) calls a 'food empire'.

Figure 6.4: Water point in one of the hills where several goat flocks and cattle herds have contact. San José de Vargas, Michoacán

A World Bank report (Banco-Mundial, 2007) emphasized win-win scenarios for agribusiness chains and smallholder farmers as a way out of poverty for the latter, but the report neglects farmers struggles for development, which are rooted in power relationships between farmers and the global agribusiness (Oya, 2009).

Power relationships are dynamic processes, so, opportunities for change occur (Villarreal, 1994; de Haan and Zoomers, 2005). Villareal's analysis shows that subordination and compliance is central in understanding how power is maintained and negotiated. Chapter 2 shows that smallholder goat farmers are also subordinated because they have an active role in their subordination themselves. They refer to the caramel manager as *'el patrón'* (the boss) (Chapter 2). The caramel industry sets the price of the milk, farmers not having power to negotiate a better price. Farmers do claim cash credits from the caramel industry when milk yields drop. Credits are granted without interest rates but in return the credit provider gains farmers' loyalty. At present, it seems not possible to counteract the power of the industry. Farmers' community social capital showed ambivalence, on the one hand farmers share tasks such as herding and milking goats and going jointly in business to buy crop residues and grow alfalfa, on the other hand rivalry between households, violence in two of the study vil-

lages, and lack of cooperation to negotiate with the dairy industry, revealed that community social capital is weak (Chapter 2).

The caramel industry concerns are milk quantity and quality in fat and protein content and more recently somatic cells count. Farmers are penalized if the caramel company finds low fat and protein content in milk diluted with water. But the company treats better-off farmers, who deliver more milk, with a slightly higher price, about ¢50 of a peso/litre of milk. But there are no economic incentives for farmers to produce milk from brucellosis 'free' flocks. Under the current market conditions, brucellosis control is therefore not appealing to farmers. In sum, caprine brucellosis and the institutional context in which farmers are presently embedded makes farmers vulnerable (Chapter 2, 5). Brucellosis control could help reduce smallholder farmers' vulnerability and enhance their livelihoods by making them more resilient. When brucellosis control is accompanied with a niche market of buyers who are willing to pay a higher price for high quality goat dairy products and safe to eat, i.e. uncontaminated by *Brucella*, smallholders could also reduce their dependency on migration and remittances because as Kay (2008) stated the latter livelihood strategies come at high price, especially for undocumented farmers.

6.3 BEYOND THE VETERINARY SCIENCE PARADIGMS OF BRUCELLOSIS CONTROL AND ERADICATION

As brucellosis is a ubiquitous zoonosis, there is a wealth of scientific information, tools and experiences for its control. Much of the scientific information comes from the experiences in the eradication of brucellosis in the global North. However, some of the paradigms concerning brucellosis control may not hold true worldwide.

VACCINATION AGAINST BRUCELLOSIS IS INEXPENSIVE

Numerous research articles in peer-reviewed journals have suggested that brucellosis control in small ruminants in the global South needs to rely on mass vaccination (Blasco, 2010; Smits, 2013) and that this is the most effective way to start with the control of brucellosis. The efficacy of vaccination is irrefutable; in countries like Tajikistan and in Greece the prevalence was reduced using vaccination (Minas et al., 2004; Ward et al., 2012). In Chapter 3, it is shown that the seroprevalence of brucellosis in goats was reduced due to vaccination with Rev 1. The odds to test seropositive were about 3.1 higher for goats of Jalisco where brucellosis control in goats was negligible compared to goats of Michoacán where vaccination of flocks was almost 100% (Chapter 3). The success of the mass vaccination in Michoacán can be explained by a good adoption rate by farmers who were not charged to have their flocks vaccinated (Chapter 5). In Jalisco state however, the control based on vaccination did not turn into success in part because farmers were charged for the cost of the vaccine, 10 Mexican pesos (inclusive the subsidy) and in other cases the service was not offered to them at all.

In Chapter 4, the modeling shows that brucellosis control via vaccination is economically rewarding in a five-year-period. The assumption was that the cost of the vaccine was 10 Mexican pesos (about .80 US$) and that this was paid by the farmer. The cost/benefit ratio

of applying the vaccine is 3.8 MX$ (Mexican pesos) [1] and the net present value is 3.2 MX$, which represents ∼ 10,000 US$ in a five-year-period if vaccination would be applied to the goat population of the region (Chapter 4). This is a thin reward for the goat sector considering that is for the whole region, but still a positive result. The Mexican regulation with regard to brucellosis states that brucellosis vaccination needs to be done by certified veterinarians. Handling Rev 1 vaccine is dangerous because it is virulent in humans. Veterinarians involved in the campaign are required to pass a theoretical test every two years to get a license for applying Rev 1. Vaccination against other pathogens like *Clostridium*, which are applied directly by farmers (Chapter 5) can be nine times cheaper compared to vaccination against *Brucella*. A flock vaccinated (37 goats) against brucellosis could cost 30 US$, which is the equivalent of eight days of the poverty threshold income. So in fact, mass vaccination in goats with Rev 1 is expensive for a Mexican smallholder goat farmer. Thus, finding ways to reduce the costs for having goats vaccinated is needed.

Roth et al. (2003) modeled the economic benefits of vaccination of cattle and sheep in Mongolia. The benefits were substantial; three times higher than the cost of the intervention for the whole country in a 10-year-period (about US$ 18 Million), when the impact on human health was taken into account. To see whether the benefits outweigh the costs of mass vaccination, and by how much, still has to be done in Mexico. Perhaps the benefits massively outweigh vaccination costs if the impact of brucellosis on human health and on other livestock sectors is taken into account.

ONLY FARMERS NEED TO BE INFORMED AND TRAINED

It is often suggested that farmers need to be educated about brucellosis (Smits, 2013). Indeed brucellosis, is a relatively new term for farmers (Chapter 5). Often farmers avoid drinking goat milk because they know it causes fever, what they call *'la fiebre malta'* ('Malta fever'),–which they do not always associate with brucellosis in goats. Furthermore, the impact on goat health is not directly visible, which is another reason they give more priority to the control of other diseases in goats (Chapter 5). But not only farmers need to be informed about brucellosis, other stakeholders such as veterinarians need to gain more knowledge in management practices (Chapter 5).

Vaccination with Rev 1 is known to cause abortion when it is applied to pregnant goats (Blasco, 1997). But some flocks were vaccinated during the breeding season causing unnecessary losses due to abortion (Chapter 5). The vaccine Rev 1 can cause abortion indeed if goats are vaccinated when they are pregnant. The assumption made in our estimation in Chapter 4 is that vaccination is applied when goats are not pregnant. Veterinarians probably know that Rev 1 causes abortion, they have to pass a test every two years, but they are most likely not fully aware that the smallholder goat husbandry system in Bajío has a controlled breeding season.

Figure 6.5, shows that vaccination should take place in February and March in the village of Labor Vieja, Jalisco. Three factors are in favor if the vaccination is done at this time. First, milk production is peaking, which means that farmers have relatively more cash and thus are in a much better financial position to contribute to the cost of the vaccination compared to periods when milk production is low. Second, the mating season starts around March so the

1 In 2008 the exchange rate of a Mexican peso (MX$) US$ 0.08, € 0.06 and £ 0.05 (Banxico, 2008)

chances of side effects, i.e. abortion, are minimized. Third, in this village four or five flocks are combined to make one single large flock to graze crop residues in relatively distant plots. Thus, it would be easier and probably cheaper to vaccinate goats grouped in a large flock than having to visit individual flocks. A slightly different breeding management was observed in Michoacán villages, where breeding started a month later; so timing of vaccination may be village specific. Rapid rural appraisal techniques are effective in getting acquainted with farmers practices, most important diseases in local areas and the role of livestock for farmers' livelihoods (Chambers, 1994; Dorward et al., 2005; Catley et al., 2012; Onono et al., 2013). Therefore, veterinarians and health authorities may need to be trained in using such appraisal techniques before carrying out vaccination campaigns. The results of Chapter 2 and 5 show that veterinarians and livestock production professionals and authorities are required to be more humble (Toribio and Rushton, 2012). Vaccinating pregnant goats could also be a sign of poor ethical veterinary practice. Thus, promoting standards in veterinary activities is required too.

TEST-AND-CULL OUT OF REACH IN THE GLOBAL SOUTH

Vaccination with Rev 1 does not eradicate brucellosis though it will reduce its prevalence. In the field study (Chapter 3) the effect of vaccination resembles the output of the transmission model where brucellosis drops to 12% in a five-year-period. Often model estimations are made for longer periods of 15 – 30 years, but, a five-year-period was preferred in this study. This reduces the uncertainties of economic estimates over longer time periods, and allows farmers and Mexican authorities to make plans according to the duration of administrations in Mexico: three-year (municipalities) to six-year (states-president) periods. To lower the prevalence below 3%, which is the eradication phase according to the Mexican law (SAGARPA, 1996), needs a test-and-cull strategy.

Caprine brucellosis eradication through test-and-cull is considered to be "...very difficult to achieve and is likely beyond reach in the developing world" (Godfroid et al., 2013, p245). Such a statement can be discouraging to parties involved in brucellosis control in the global South. It should be noted that the authors based their conclusion on the experience in Greece, a country of the global North. Indeed, test-and-cull is expensive but to be out of reach has not been proven fully. Test-and-cull in control plans is more expensive than vaccination alone according to the estimations made in Chapter 4. The Net Present Value ranges from -54,112 to -98,086 US$ dollars for the entire region. In Chapter 4, however, we show that a test-and-cull approach would be financially attractive if farmers could sell their milk at a higher price (3.2 times higher). How to get this 'ideal' price? Farmers' priority is a higher milk price, but their milk price has shrunk sharply during the last years (Figure 6.6). The prices started to drop in 1990 just before the signature of the NAFTA agreement in 1994. Goat milk price dynamics follows cow milk price dynamics. Mexico imports cow powder milk from the US, which has caused major price drops in cow milk in Mexico.

The industry is not yet willing to pay a premium price to milk certified free of brucellosis. I addition, in the neoliberal globalization era governments tend to favour industrial farming systems and neglect smallholder farming systems (van der Ploeg, 2013). In such a context higher subsidies are unlikely. Farmers have the opportunity to negate the dairy industry, e.g. brucellosis control could offer an opportunity to create a new market. Farmers need to work together with urban consumers so that they can offer their goat products directly to

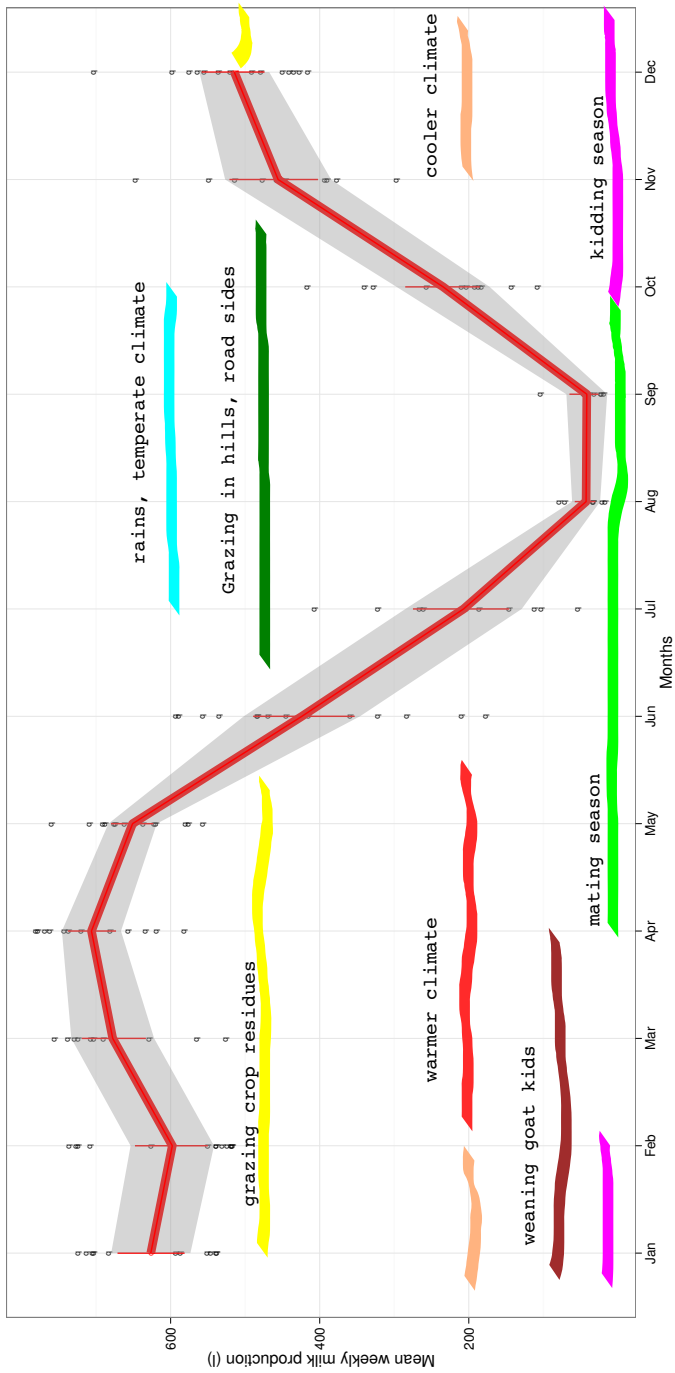

Figure 6.5: Average weekly milk yields (dots) of milk production of a goat flock, Jalisco, according to weekly records for the years 2006 to 2009. Source: Farmers' milk sales records

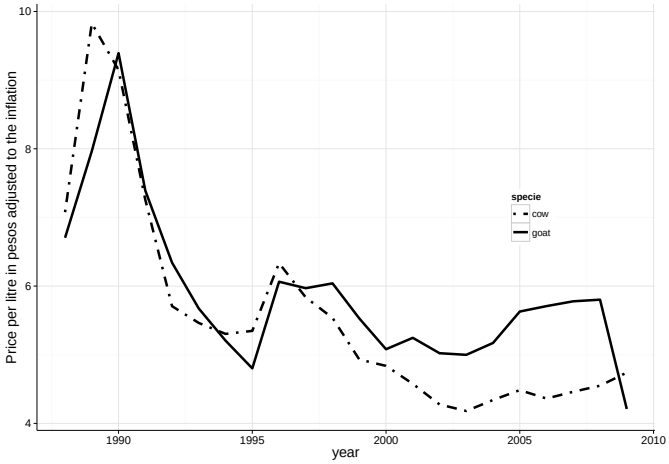

Figure 6.6: Yearly (1989-2009) goat and cow milk price variation in pesos per litre corrected for inflation. Source: SIAP (2014)

consumers avoiding middlemen, retailers and 'food empires'. Farmers in the study site are about 150 km away of Guadalajara, the second largest city in Mexico, which has a market of 4 M people. The road and communication infrastructure allows direct marketing of goat products in Guadalajara. Local initiatives like *Círculo de production* [2] are promoting farmers' markets for higher added value of smallholder farm products. Collective action of farmers would be needed to support a marketing study to ensure there is real demand and to investigate which prices will be acceptable to urban consumers. Collective action would also be needed to ensure daily availability and high product quality including brucellosis free certification. Farmers may currently lack entrepreneurial capacity, but there is an opportunity if they work together with the various business schools in the area. In sum, if farmers can create a niche market, which pays 3-fold the current milk price per litre, then test-and-cull is not out of reach in the global South.

6.4 IMPLICATIONS

REDESIGNING BRUCELLOSIS CONTROL

The discussion of brucellosis control and eradication in scientific arenas concentrates on technological advances, i.e. molecular tests and improved vaccines, and the discovery of novel *Brucella* strains (Sriranganathan et al., 2009; Godfroid et al., 2011; Whatmore, 2014). The ideal vaccine to protect goats still needs to be developed. Such a vaccine should have high efficacy and have no side effects and should be accompanied with a test that is capable to differentiate between antibodies due to vaccination and due to natural infection. A field molecular test to differentiate biovars would also be desirable, in order to obtain information

2 http://tianguisorganicos.org.mx/jalisco/circulodeproduccion/

on which biovars are involved in brucellosis in goats and to what extent *B. melitensis* is found in other livestock.

New technological advances may speed up brucellosis control, and reduce the costs, but they are not pre-requisite. No studies have looked at the problems smallholders in the global South encounter to implement brucellosis control strategies. Both social and economic factors affect the efficacy of brucellosis control policies (Chapter 5). A re-design of the brucellosis control policy will need to take into account the socioeconomic factors affecting the adoption of brucellosis control measures.

1. **Compensation** is key in the success of brucellosis control campaigns in the global North, such as in European countries where brucellosis control programmes are co-financed by national governments (Godfroid et al., 2013). A proper test-and-cull strategy needs to be implemented; such a strategy will bring down the prevalence more quickly (Chapter 4). Farmers are aware of testing because in most study villages of Michoacán and in one village of Jalisco testing has been conducted. Farmers are skeptic about the serological test outcomes, as they wonder why a productive goat can be positive to brucellosis (Chapter 5). Farmers' perceptions arise from the fact that a goat infected with *Brucella* spp. most likely will abort once but subsequent pregnancies need not be affected even in case the goat remains a *Brucella* carrier (Blasco, 2010). Test-and-cull will be very difficult to implement when farmers have to bear the costs on their own or when milk prices do not allow investment in test-and-cull. Next to test-and-cull and sharing costs, farmers need to be informed well by government, health officials and veterinarians about brucellosis and their consequences.
2. **Acknowledgement** of farmers' knowledge and experience is important in gaining support in the uptake of control measures. Various stakeholders such as milk buyers and state employees of the agricultural secretariat (veterinarians, extensionists) have low esteem of farmers arguing their lack of knowledge (Chapter 2 and Chapter 5). Often farmers' educational level and knowledge is seen as constraint for development (Budisatria, 2006; Escareño et al., 2012). In Chapter 2, ethnographic methods showed that farmers have a wealth of knowledge of the agro-ecology of the region, goat diseases, treatments, disease prevention, cropping and economics (Chapter 2). Farmers' knowledge explains partly why goat husbandry has persisted for almost 500 years and farmers have adapted production goals over time. Indeed there is room for improvement in particular with regard to brucellosis. But, farmers need to be treated as equals and as knowledgeable, which is often not done in the study area (Personal communication NGO representative). In turn, veterinarians and extensionists can gain farmer's trust and cooperation by integrating farmers' knowledge, experiences in brucellosis control actions (i.e. vaccination, test-and-cull) and practices of goat husbandry, i.e. grazing and mating.
3. **Diffussion** of knowledge about brucellosis to farmers is needed. The link between the term 'brucellosis' with 'Malta Fever' is not clear to all farmers (Chapter 5). Farmers should be better informed about the implications of brucellosis in goats and ways to prevent infections in animals and humans. Radio programmes to inform farmers about brucellosis are an option, but there is a range of other possibilities. Smits (2013) suggested the use of text messages, another possibility is to include some entertaining lectures about brucellosis for children in rural schools. In Chapter 3 various factors, i.e.

vaccination, goat density, exchange of goats, disinfection, were found to be associated with brucellosis serostatus. Bringing this knowledge to farmers, for example, by the extension programme GGAVATT will be a good start. Some of these factors can be implemented simply by farmers, i.e disinfection (Smits, 2013).

4. **Regional** organisation has been indicated for brucellosis control as *Brucella* pathogens can spread beyond administrative borders (Smits, 2013). Brucellosis control in Mexico is organised within the boundaries of administrative areas (states). Direct and indirect transmission of brucellosis among goats of two states is very likely as goats are traded between states. Second, goat flocks from Jalisco are herded to Michoacán to graze crop residues (Chapter 5), which results in direct contact with goats from Michoacán and can also expose goats to *Brucella* carrying fomites. Therefore, a strategy based on the geography of grazing patterns that goes beyond the administrative borders between states is required. The basic 'regional' unit of brucellosis control has to be the village.

   One option to plan brucellosis control actions at village level can be through the extension service. Frequently the extension service promotes the adoption of technologies that do not fit the socioeconomic and ecological conditions of smallholder farmers, i.e. milking machines, stall-fed systems, ear tagging. These technologies tend to be expensive and unsuccessful are not often complied (Chapter 2). Furthermore, the extension service works with a 'small' group of farmers (about 20) excluding others especially farmers in the lower socio-economic strata. Therefore, it is suggested that the extension service should focus on brucellosis control at village level, including both the cattle and small ruminant population. This may also solve the lack of veterinarians reaching remote villages as reported in one of the villages of Jalisco.

6.5 FUTURE RESEARCH

The majority of the epidemiological studies in the global South are based on serology, such as in Chapter 3. Serology does not discriminate between *Brucella* species and cross infections between cattle and small ruminants are not detected (Godfroid et al., 2013). Epidemiological and bacteriological research that identifies which *Brucella* species is involved is needed. Added to this brucellosis does not recognize borders (Pappas, 2010); the spatial distribution of the disease within Mexico in the neighbouring countries in Central and North America will be needed for a regional brucellosis control plan. Point-of-care testing to diagnose brucellosis (e.g. Clavijo et al., 2003) in farmers is needed to estimate the current costs of brucellosis endemicity in the country; the estimations made in Chapter 4 do not consider the impact of human brucellosis due to lack of epidemiological data on human brucellosis.

Leach and Scoones (2013) conclude that interdisciplinary teams will be needed to better tackle brucellosis and other neglected zoonoses in the global South. The use of interdisciplinary methods is not perfect in our study, although the integration of results from the different disciplines was fruitful. Insights using ethnographic methods help to understand goat husbandry management and farmers perceptions with regard to brucellosis. Apart from farmers, perceptions of veterinarians and government staff should also be included in future studies, in order to design an improved approach to the brucellosis campaign that integrates different types of knowledge and attitudes.

This thesis refers to the 'One Health' concept in Chapter 4, a concept that takes the animal/ecosystem/human interface in the control, eradication and surveillance of brucellosis into account (Godfroid et al., 2011). In Chapter 5 a framework based on Dixon et al. (2013) was used to understand the social and economic factors that shape farmers perceptions and where the 'physical environment' plays a role. Integration of animal/ecosystem/human dimensions in research is still challenging and much needs to be learned, especially with the re-emergence of brucellosis in wildlife in the global North and in ocean mammals (Sriranganathan et al., 2009). More research on brucellosis is necessary because in the opinion of Pappas (2010) brucellosis is the most neglected disease in terms of morbidity and socioeconomic effects. In this thesis, little attention has been paid to cultural factors. These factors are important in the livelihoods and zoonoses domains because they play a role in the success of programmes aimed at prevention of zoonotic diseases, or poverty alleviation (Bebbington, 1999; Dixon et al., 2013). Future research will therefore need to include cultural capital of goat husbandry as well.

6.6 CONCLUSIONS

- Goat husbandry enjoys growing interest among farmers, partly because cropping has become economically risky and less profitable. Goat husbandry is dairy oriented; it is a source of weekly income, insurance, and a reason for not having to migrate to the US. Households have strengthened other capitals (social, human, and natural) through goat husbandry. But these success stories are limited. The potential of goat husbandry as a tool for poverty alleviation has not been fully exploited yet (Chapter 2).
- Given the relatively low amount of crop land available for each household we showed that small-scale goat husbandry is productive, which contrasts with the dominant discourse in Mexico that smallholder systems are 'unproductive' (Chapter 2).
- The prevalence of testing positive to brucellosis was higher (38 %) in Jalisco than in Michoacán (11 %). Goats in zero-grazing systems had lower risk of being tested brucellosis positive than goats in grazing systems. If goats were kept in pens with low density risk of testing positive was lower compared to goats kept in pens with higher densities. Regular disinfection of the pen reduced the odds compared to where disinfection was not regular (Chapter 3).
- Brucellosis control based on a strategy of vaccination is predicted to be economically profitable at current milk prices. The Net Present Value for the goat population of the region was 123,078 pesos, $\sim$ US$ 10,000 over five years (Chapter 4).
- There is a two way lack of communication: farmers know little about brucellosis and policy makers and veterinarians know little about small-scale goat husbandry management and farmers' perceptions (Chapter 5).
- Brucellosis control will need to be escorted with an effective organization and planning. Trading of seropositive goats and vaccination when goats are not pregnant should be prevented. Furthermore, an identification system that fits with extensive grazing is needed. Controlling brucellosis in both cattle and goat populations using a regional approach that goes beyond the administrative borders is required (Chapter 5).

- Only when government and/or the dairy industry support goat farmers through subsidies or milk price increases, test-and-cull systems are acceptable for farmers. This would be a major reduction in prevalence to near zero (Chapters 4, 5, 6).
- It is urgent to establish the real prevalence of human brucellosis, and to determine the effects on human welfare and economic costs. A joint approach by the medical, veterinary and administrative bodies at national and regional level could strengthen understanding and collaboration in future campaigns to eradicate brucellosis and support surveillance (Chapter 6).
- Smallholder goat husbandry could have the potential to alleviate poverty in Mexico, especially in rural areas, where extreme poverty is endemic (Chapter 1, 6).
- Smallholders need to strengthen their social capital, and work together to create a niche market willing to pay for certified brucellosis free milk products. This niche market can be created in the metropolis of Guadalajara (Chapter 6).

7

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SUMMARY

The number of poor people at global level is remaining high despite the millennium goal to reduce poverty by half in 2015. In the global South three out of four people in poverty are from rural areas. Goats are usually kept by farmers belonging to the poorer groups. Goats are a source of meat and milk, and have also social and cultural functions. They are renowned for their resilience in harsh environments and they are relatively cheap to acquire. Goat husbandry is often promoted as a tool for poverty alleviation. Smallholder goat farmers are, however, often operating in a complex context characterised by unfavorable policies, e.g. limited access to subsidies and credits. In Mexico migration of farmers is one of the impacts of neoliberal policies. The North American Free Trade Agreement (NAFTA), signed between Mexico, the United States (US) and Canada in 1994, caused a substantial drop in the domestic price of agricultural products and in agricultural employment. Many farmers, therefore migrated to the United States as a way to diversify their income sources. Remittances are invested in farming activities, such as cropping but also in livestock husbandry, goat husbandry being one of them.

The Mexican goat population is currently 4 million, with 260 thousand goat farmers. The bulk of the goat population is in hands of smallholder farmers, that keep goats in extensive grazing systems. Caprine brucellosis is one of the constraints in goat husbandry as it negatively affects production parameters. This might counteract the potentially positive impact of goats on livelihoods, even more because brucellosis can be transmitted to humans.

In Mexico, brucellosis control started in 1971, yet it is endemic in the livestock population. Caprine brucellosis is caused by *Brucella melitensis* and transmission occurs through direct and indirect contact with infected animals or contaminated fomites. The infection may induce placentitis in does which results in abortion in the last third of pregnancy and is also associated with premature births and placenta retention; whereas in bucks it causes orchitis. The consequences will have a negative impact on flock productivity and on the economic value and welfare of the animal. *B. melitensis* is the most pathogenic *Brucella* species in humans. Although brucellosis is rarely a fatal disease in humans, who are accidental hosts, it can be very debilitating and disabling. A general symptom of brucellosis is undulant fever, but complications such as arthritis and spondylitis are common.

The main objectives of this thesis were to assess the impact of brucellosis on smallholder goat husbandry and to evaluate brucellosis control strategies in enhancing farmers' livelihoods.

The research approach chosen was that of a case study in order to understand how caprine brucellosis control has been addressed. The case study was conducted in two states within the Bajío region: Michoacán and Jalisco. The two states share an area that is interesting with regard to brucellosis control – trading of goats and goat products is common between villages of both states and also the implementation of brucellosis control measures is different between the two states. The study followed the 'DEED' framework, acronym of Description, Explain, Explore and Design. Therefore, first the historical background of goat husbandry and the current status of brucellosis in Mexico were **described** (Chapter 1). In Chapter 2, based on livelihoods approaches, farmers' livelihoods are **described** in the context of social and economic drivers, e.g. migration and neoliberal policies. Two cross-sectional surveys, one with farmers (N=46), and one with farmers' neighbours (N=145), were carried out in four villages of Michoacán. The farmers' survey was used to characterize smallholders' livelihoods assets by their socio-economic strata (poor, medium and better off). In this survey we also investigated how goat husbandry was valued by households; this included identifica-

tion of the different functions of goat husbandry and which other strategies smallholders had. The second survey aimed to understand goat farmers' neighbours views on goat husbandry. Chapter 3 reports on the results of an epidemiological survey that included 1,713 goats of 83 flocks to **explain** differences in seroprevalence and to identify and quantify risk factors of brucellosis. In Chapter 4 options for control were **explored** based on a combination of models: (1) a brucellosis transmission model at village flock level (n = 1000 head), (2) a flock growth model at smallholder flock level (n = 23 head) using output of model 1 and (3) a financial analysis of several brucellosis control scenarios based on output of model 2. Here, veterinary epidemiology outputs were put in context to assess the feasibility of the control strategies: vaccination, test-and-cull, a combination of both, and the strategy of no control. In Chapter 5, exploration of control options is taken one step further by incorporating farmers' perceptions, influenced by their frame of reference (i.e. practices, knowledge, interests, beliefs and experiences). Farmers' perceptions were assessed through ethnographic methods and rural appraisal techniques. In Chapter 6, a re-**design** of the brucellosis control campaign is presented based on the results described in Chapters 1 to 5.

There is a relatively long history of about 500 years of goat husbandry in the region. Smallholders deploy a range of assets to be involved in goat husbandry. Goat husbandry is dairy oriented; it is a source of weekly income, food, insurance, credit, and a reason for not having to migrate to the US (Chapter 2). Furthermore, goat husbandry is valued as an apprenticeship for farmers' children, and gives farmers prestige in the villages. In general, farmers have a high esteem among their neighbours, who refer to them as '*gente de trabajo*' (working people) (Chapter 2).

Goat farmers had a rich knowledge of keeping goats, taking advantage of the local vegetation and farming cycles to feed their flocks (Chapter 2). Farmers' relatively good social capital allowed them to access cheap crop residues and take turns for herding flocks. Poor households had on average 37 goats, and goat husbandry was one of their main livelihoods strategies. Better-off and medium group households had a wider range of activities. The goat dairy market was controlled by the caramel industry, and the margins farmers obtained were rather limited. The gross margins per capita of poor farmers in MX$ (median = 4,987, IQ = 3,895 - 11,948) and medium farmers (median = 9,029, IQ = 7,736 - 11,723) were under the poverty line. Farmers considered, however, that they were better off than farmers who did not keep goats 'it is better to herd than to be herded'. In only about half of the farmers' households goat dairy products were consumed and raw milk was avoided as it was seen as a cause of 'fever', related to brucellosis, also known as Malta fever (in humans). Farmers, however, did not always know that brucellosis and Malta fever are synonyms, neither were they aware of the economic impacts of brucellosis (Chapter 5). The magnitude of brucellosis prevalence at the study site is presented in Chapter 3. The prevalence of testing positive to brucellosis was higher (38%) in Jalisco, than in Michoacán (11%). Logistic regression analysis indicated that goats from Michoacán had lower odds to test positive for brucellosis (OR=0.32, 95% CI 0.21-0.48) compared to goats from Jalisco. Goats in zero-grazing systems had lower odds than goats in grazing systems (OR=0.22, 95% CI 0.09-0.57). Odds were higher for testing positive when farmers bought goats from goat traders (OR=1.82, 95% CI 1.15-2.87) compared to farmers who did not. When goats were kept in pens with low density (0.002 to 0.22 goat/m^2) odds were lower (OR=0.4, 95%CI 0.3-0.8) compared to goats kept in pens with higher density (0.23 to 1 goat/m^2). When poultry had access to goats pen the odds were half (OR=0.52, 95% CI 0.33-0.83) of those where poultry had no access. Regular disinfection of the pen reduced the odds (OR=0.66, 95% CI 0.44-0.99) compared to where disinfection was not regular. It was concluded that the lower prevalence in Michoacán, shows that the brucellosis control campaign in this state was more effective in reducing brucellosis seropositivity than the campaign in Jalisco.

In Michoacán the uptake was almost complete because the service was for free, whereas in Jalisco vaccination was not adopted thoroughly because the farmers had to bear part of

the cost of vaccination and because there was a lack of veterinarians offering the services (Chapter 5). Farmers are thus not aware of the relevance of brucellosis control and are not prepared to bear high costs. In Chapter 4 a financial analysis is presented. The net present value (NPV) of using vaccination was 3.2 Mexican Pesos (MX$) per goat and the benefit/cost ratio was 3.8. The NPV for the goat population of the region was MX$ 123,078 ($\sim$ US$ 10,000) over five years. Thus, the impact of vaccination with Rev 1 on the reduction of seroprevalence shows to be slightly positive at regional level. However, brucellosis prevalence was predicted to remain relatively high: about 12%. Control scenarios with test-and-cull predicted to reduce brucellosis prevalence to less than 3%, but this coincided with a negative NPV ranging from MX$ -676,407 to - 1,226,085. In conclusion: a brucellosis control campaign based on vaccination with full coverage is economically profitable for the goat dairy sector of the region. Smallholders cannot bear the costs themselves in case test-and-cull is applied in order to reduce the prevalence to levels below 3%. Currently, however, culling of suspected infected goats does not happen and an adequate infrastructure for culling does not exist. It should be ensured that goats that test brucellosis seropositive are not sold to other farmers. Furthermore, farmers perceive that brucellosis control measures cause losses such as abortion due to untimely vaccination and ear infections due to ear tagging. Chapter 5 disputes the idea that brucellosis is only due to the lack of awareness and participation of farmers related to control measures, but rather there is a two way lack of communication: farmers are not informed well about what exactly brucellosis is about and policies are implemented without knowing thoroughly farmers perceptions and goat farming practices.

In Chapter six, the general discussion, the following questions are addressed: Is goat husbandry a pathway out of poverty? Is brucellosis a constraint to alleviate poverty? How can brucellosis be controlled? Based on the livelihoods approaches it is shown that the role of goat husbandry for smallholder farmers livelihoods is ambivalent, on the one hand it shows that goat husbandry can make farmers more resilient on the other hand the low price of goat milk and brucellosis in the goat population puts farmers' livelihoods in a vulnerable position. There are ample recommendations for the control of brucellosis but these are not applicable fully in Mexico, as is the case in other countries of the global South. Three paradigms related to brucellosis control are contested. First, *vaccination is inexpensive*, but vaccination costs are high for farmers and for the state, partly because vaccination has to be done by licensed veterinarians. Second, *only farmers need to be trained to control brucellosis*, indeed farmers lack knowledge about brucellosis but veterinarians and health authorities know little about goat husbandry management. Therefore all stakeholders need to learn about brucellosis and about goat husbandry management in order to gain mutual understanding. Third, *test-and-cull are out of reach in the global South*. Indeed the costs for culling are high; however, brucellosis eradication through test-and-cull should be possible especially if a niche market for dairy goat products can be realized. Brucellosis control is an opportunity to 1) access a better market, 2) prevent migration to the the North, and 3) enhance farmers' health and welfare, i.e. their livelihoods.

Brucellosis control is an opportunity for smallholder goat farmers in enhancing their livelihoods. The policy for brucellosis control needs to be redesigned. Four factors are important to consider in the designing of a new policy; first, a comprehensive compensation for losses when planning test-and-cull; second, the acknowledgement and integration of farmers expertise and experience in the design of control interventions; third, diffusion of knowledge about brucellosis control, prevention and the impact on human health and livestock production; fourth, a regional planning is a must to succeed.

SAMENVATTING

Wereldwijd leven nog steeds veel mensen in armoede, ondanks het millenniumdoel dat armoede in 2015 met de helft moet zijn teruggebracht. In derde wereld landen woont driekwart van de mensen onder de armoedegrens op het platteland. Het houden van geiten wordt aangemoedigd om armoede te bestrijden. Geiten zijn een bron van vlees en melk en hebben maatschappelijke en culturele functies. Ze staan bekend om hun robuustheid onder moeilijke omstandigheden en zijn relatief goedkoop. Kleinschalige geitenhouders hebben echter vaak te maken met ongunstige omstandigheden, zoals beperkte toegang tot subsidies en leningen. De Noord-Amerikaanse vrijhandelsovereenkomst (NAFTA), een in 1994 opgerichte vrijhandelszone tussen Mexico, de Verenigde Staten en Canada, veroorzaakte een prijsdaling in landbouwproducten en een daling in agrarische werkgelegenheid. Veel Mexicaanse boeren emigreerden als gevolg van dit neoliberale beleid naar de Verenigde Staten om hun inkomen te verhogen. Naar familie overgemaakte inkomsten worden geïnvesteerd in landbouwactiviteiten, zoals akkerbouw en veeteelt, waaronder geitenhouderij.

In Mexico worden 4 miljoen geiten gehouden door 260.000 boeren. De meerderheid van de geiten wordt gehouden in extensieve beweidingssystemen en door kleinschalige boeren. De infectieziekte brucellose kan het positieve effect van het houden van geiten op armoede teniet doen, ook omdat de ziekte op mensen overdraagbaar is.

Ondanks de bestrijding van brucellose in Mexico sinds 1971 komt de ziekte nog steeds voor in de veestapel. Brucellose bij geiten wordt veroorzaakt door *Brucella melitensis* en besmetting gebeurt door direct en indirect contact met geïnfecteerde dieren en gecontamineerde materialen. Infectie kan onder andere spontane abortus en vroeggeboorte veroorzaken bij drachtige geiten en orchitis bij bokken. De gevolgen zijn negatief voor de productiviteit van de kudde, de economische waarde en het welzijn van het dier. *B. melitensis* is de meest pathogene Brucella soort voor mensen. Hoewel brucellose voor mensen zelden dodelijk is, kan de ziekte mensen verzwakken en belemmeren in hun dagelijks leven. Een veelvoorkomend symptoom van brucellose bij mensen is koorts en complicaties als gewrichts- en wervelontsteking komen vaak voor. Het doel van dit proefschrift was om de gevolgen van brucellose op kleinschalige geitenhouderijen te evalueren en om de effecten van bestrijding van brucellose op het levensonderhoud van boeren te bepalen.

Het onderzoek werd uitgevoerd in twee Mexicaanse staten, Michoacán en Jalisco in de Bajío regio, verschillend in de aanpak van de bestrijding van brucellose bij geiten. Beide staten delen een gebied waarin veelvuldig tussen dorpen wordt gehandeld in geiten en producten van geiten. De studie is uitgevoerd volgens de 'DEED' methode, een acronym voor beschrijven (Description), verklaren (Explain), onderzoeken (Explore) en ontwerpen (Design). Eerst zijn de historische achtergrond van de geitenhouderij en de huidige stand van zaken met betrekking tot brucellose in Mexico **beschreven** (hoofdstuk 1). In hoofdstuk 2 zijn de levensomstandigheden van boeren **beschreven** in de context van maatschappelijke en economische drijfveren, zoals migratie en het neoliberale beleid. Twee dwarsdoorsnede studies, één onder boeren (n=46) en één onder omwonenden (n=145), zijn uitgevoerd in vier dorpen in Michoacán. In de eerste studie werden kleinschalige boeren ingedeeld in drie sociaal-economische klassen: arm, gemiddeld en rijk. In deze studie is ook **onderzocht** wat de waarde van het houden van geiten was, waarbij de verschillende functies van de geitenhouderij en de nevenactiviteiten in kaart zijn gebracht. De tweede studie inventariseerde de mening van omwonenden over geitenhouderij. Hoofdstuk 3 beschrijft de resultaten van een epidemiologische studie naar 1713 geiten in 83 kuddes om verschillen tussen bedrijven in prevalentie van brucellose te **verklaren** en risicofactoren te kwantificeren. In hoofdstuk 4

zijn mogelijkheden voor het bestrijden van brucellose **onderzocht** met behulp van modellen: (1) een brucellose transmissie-model op dorpsniveau (n=1000 geiten), (2) een groeimodel op kleinschalig kudde niveau (n=23 geiten) gebaseerd op resultaten van model 1 en (3) een economische analyse van verschillende scenario's van brucellosebestrijding gebaseerd op resultaten van model 2. De epidemiologische resultaten zijn in hun context geplaatst om de haalbaarheid van de volgende strategieën te evalueren: vaccinatie, testen en afvoeren van positieve dieren, een combinatie van vaccineren en afvoeren en een scenario zonder bestrijding. Hoofdstuk 5 is een verdieping van het onderzoek naar mogelijke bestrijdingsscenario's. Het bestudeert de opvattingen van de boeren, die door hun kennis, ervaringen en belangen worden beïnvloed. Hoofdstuk 6 presenteert een nieuw **ontwerp** voor een brucellose bestrijdingscampagne, gebaseerd op de resultaten uit hoofdstuk 1 tot en met 5.

De geschiedenis van het houden van geiten in de regio gaat tot zo'n 500 jaar terug. Geiten worden gehouden voor de productie van zuivel; ze zijn een wekelijkse bron van inkomsten, voeding, een verzekering, onderpand voor krediet en een reden om niet naar de Verenigde staten te hoeven emigreren (hoofdstuk 2). Bovendien is de geitenhouderij van waarde om kinderen ervaring op te laten doen en geeft het status in de dorpen. Over het algemeen hebben omwonenden veel respect voor geitenhouders, die 'gente de trabajo' (werkende mensen) worden genoemd (hoofdstuk 2).

Geitenboeren hebben veel kennis over het houden van geiten, ze maakten wisselend gebruik van de lokale vegetatie en akkerbouw om hun kuddes te voeren (hoofdstuk 2). Door relatief goede sociale netwerken hebben de boeren toegang tot goedkope gewasresten en hoeden ze per toerbeurt de kuddes. Armere huishoudens hadden gemiddeld 37 geiten en het houden van geiten was voor hen één van de belangrijkste bronnen van inkomsten. Rijkere en gemiddelde huishoudens hadden meer nevenactiviteiten. De zuivelmarkt wordt gedomineerd door de caramelindustrie. De inkomsten van de boeren waren beperkt. De brutomarge per capita voor de armere (mediaan (MX$) = 4.987, IQR = 3.895 – 11.948) en gemiddelde (mediaan = 9.029, IQR = 7.736 – 11.723) boeren was onder de armoedegrens. Toch waren de geitenhouders van mening dat ze beter af waren dan boeren die geen geiten hielden, zie de uitspraak 'het is beter om een kudde geiten te hoeden dan om gehoed te worden'. Slechts in de helft van de boerenhuishoudens werden zuivelproducten van geiten geconsumeerd. Drinken van rauwe melk werd vermeden omdat het als bron van besmetting en als oorzaak van 'koorts' werd gezien. Boeren wisten echter niet altijd dat brucellose en Malta-koorts bij mensen synoniemen zijn, en evenmin waren ze zich bewust van de economische gevolgen van brucellose (hoofdstuk 5). De prevalentie van brucellose bij geiten in de bestudeerde gebieden is beschreven in hoofdstuk 3. De prevalentie van positieve testuitslagen was hoger in Jalisco (38%) dan in Michoacán (11%). Logistische regressie analyse liet zien dat geiten uit Michoacán een lagere kans hadden op een positieve testuitslag (OR=0.32, 95% CI=0.21-0.48) dan geiten uit Jalisco. Geiten zonder weidegang hadden een lagere kans dan geiten die wel geweid werden (OR=0.22, 95% CI=0.09-0.57). De kans op een positieve testuitslag op brucellose was hoger wanneer boeren geiten aankochten van handelaren (OR=1.82, 95% CI=1.15-2.87). Geiten die in lagere dichtheden werden gehouden (0.002 tot 0.22 geit per m2) waren minder vaak positief dan geiten die in hogere dichtheden werden gehouden (0.23 tot 1 geit per m2). Waar pluimvee toegang tot de geitenstal had was de kans om positief te testen half zo groot (OR=0.52, 95% CI=0.33-0.83) dan waar pluimvee geen toegang tot de stal had. Regelmatige desinfectie van de stal verlaagde de kans (OR=0.66, 95% CI 0.44-0.99) in vergelijking met geen regelmatige desinfectie. Uit de lagere prevalentie van brucellose in Michoacán kan geconcludeerd worden dat de campagne in deze staat effectiever was in het bestrijden van brucellose dan de campagne in Jalisco.

In Michoacán werd door bijna alle boeren gevaccineerd tegen brucellose omdat dit gratis was, terwijl vaccinatie in Jalisco veel minder werd toegepast omdat de boeren een deel van de kosten zelf moesten betalen en vanwege een tekort aan gecertificeerde dierenartsen (hoofdstuk 5). Boeren waren zich niet bewust van het belang van de bestrijding van brucellose

en waren niet bereid de kosten te betalen. Hoofdstuk 4 geeft een economische analyse. De netto contante waarde (NCW) van de brucellose vaccinatie per geit was 3,2 Mexicaanse Pesos (MX$) en de baten/kostenverhouding was 3.8. De NCW voor de hele populatie geiten in het gebied was MX$ 123.078 wat overeenkomt met US$ 9.846. Het effect van de vaccinatie met Rev 1 op de afname van de prevalentie van brucellose is dus positief op regionaal niveau. De modellen voorspelden echter wel dat brucellose prevalentie na vaccinatie vrij hoog bleef, ongeveer 12%. Strategieën met testen en afvoeren van zieke dieren verminderden de prevalentie van brucellose tot minder dan 3%, maar hadden een negatieve NCW van -676.407 tot -1.226.085 MX$. Uit de resultaten kan geconcludeerd worden dat een brucellose vaccinatie campagne winstgevend kan zijn voor de geitensector in de regio. Kleinschalige boeren kunnen de kosten niet zelf dragen wanneer het testen en afvoeren van positieve dieren wordt toegepast om de prevalentie van brucellose terug te dringen tot minder dan 3%. Momenteel worden brucellose verdachte dieren niet afgevoerd en is er geen infrastructuur om dit goed te kunnen doen. Er moet worden verhinderd dat geiten die positief zijn doorverkocht worden aan andere boeren. Verder hebben boeren de opvatting dat de maatregelen om brucellose te bestrijden verliezen veroorzaken door spontane abortus als gevolg van vaccinaties op een verkeerd moment en door oorinfecties als gevolg van het aanbrengen van vaccinatie-oormerken. In hoofdstuk 5 wordt het idee in twijfel getrokken dat brucellose alleen voorkomt door gebrek aan bewustzijn, kennis en medewerking van geitenhouders, en wordt beargumenteerd dat er eerder een tweezijdig gebrek is aan communicatie: enerzijds zijn boeren niet goed geïnformeerd over brucellose en anderzijds wordt beleid geïmplementeerd zonder rekening te houden met de praktijksituatie en de opvattingen van boeren.

Hoofdstuk 6, de algemene discussie, stelt de volgende vragen: is het houden van geiten een uitweg uit armoede? Is brucellose een beperking bij het verminderen van armoede? Hoe kan brucellose worden bestreden? De levensonderhoudbenadering laat zien dat de rol van het houden van geiten voor kleinschalige boeren tweeërlei is. Enerzijds kan het houden van geiten bijdragen aan het levensonderhoud, anderzijds zorgen de lage prijs voor geitenmelk en de brucellose prevalentie in de populatie voor een kwetsbare positie. Er zijn veel aanbevelingen voor de bestrijding van brucellose, maar deze zijn niet volledig toepasbaar in Mexico, net als in andere derde wereld landen. Drie paradigma's over brucellose worden betwist. De eerste, vaccinatie is goedkoop, omdat vaccinatie kosten hoog zijn voor boeren en voor de staat, gedeeltelijk ook omdat vaccinatie moet worden uitgevoerd door gecertificeerde dierenartsen. De tweede, boeren moeten leren om brucellose te bestrijden, omdat, hoewel het weliswaar zo is dat boeren niet altijd kennis hebben van brucellose, dierenartsen en autoriteiten weinig weten over de praktijksituatie in de geitenhouderij. Daarom moeten alle betrokken partijen hun kennis over brucellose en praktische kennis van geitenhouderij verhogen om wederzijds begrip te kweken en on effectieve een effectieve bestrijding mogelijk te maken. Het derde paradigma is het testen en afvoeren van zieke dieren is geen optie in derde wereld landen. De kosten voor afvoer zijn inderdaad hoog, maar het uitbannen van brucellose zou met deze strategie mogelijk moeten zijn, vooral wanneer er een niche-markt voor zuivelproducten van geiten kan worden gerealiseerd. Bestrijding van brucellose is een kans om 1) toegang te krijgen tot een betere markt, 2) emigratie naar het noorden te verhinderen en 3) de gezondheid en het welzijn van geitenhouders te verhogen. Het bestrijden van brucellose vergroot de kans voor kleinschalige geitenhouders om hun levensstandaard te verbeteren. Het beleid voor de bestrijding van brucellose moet worden herontworpen. Met vier factoren moet hierbij rekening worden gehouden; ten eerste, een compensatie voor het verlies wanneer positief op brucellose geteste dieren moeten worden afgevoerd; ten tweede, de erkenning en integratie van expertise en ervaring van de boeren in het ontwerpen van een bestrijdingsstrategie; ten derde, verspreiding van kennis over de bestrijding en het voorkomen van brucellose en de gevolgen van brucellose op humane gezondheid en productie van de veestapel; ten vierde is een regionale aanpak noodzakelijk om een bestrijdingsprogramma succesvol te laten zijn.

RESUMEN

El número de pobres a nivel mundial permanece alto a pesar de la meta del milenio de reducir la pobreza a la mitad en el 2015. En el Sur Global tres de cada cuatro personas en zonas rurales viven en pobreza. Generalmente, los campesinos más pobres son los que tienen cabras. Las cabras son una fuente de carne y leche, y tienen también tienen funciones sociales y culturales. Las cabras son reconocidas por su capacidad de resistencia en ambientes hostiles y son relativamente baratas de adquirir. La crianza de cabras a menudo se promueve como una herramienta para reducir la pobreza. Sin embargo, los pequeños productores de cabras operan en un contexto complejo caracterizado por políticas desfavorables, por ejemplo, el limitado acceso a subsidios y créditos. En México, la migración de los campesinos es uno de los impactos de las políticas neoliberales. El Acuerdo de Libre Comercio de Norteamérica (NAFTA), firmado entre México, los Estados Unidos de América y Canadá en 1994, provocó una caída sustancial en los precios internos de los productos agrícolas y del empleo agrícola. Esto dio pie a que muchos pequeños productores emigraran a Estados Unidos como una forma de diversificar sus fuentes de ingresos. La migración ha servido en parte para mantener a flote la actividad agrícola de muchos pequeños productores del país, porque las remesas se invierten en actividades agrícolas, como cultivos, y también en la crianza de ganado, como es el ganado caprino.

La población de cabras en México es actualmente de 4 millones, con 260 mil productores. El grueso de la población de cabras está en manos de pequeños productores, que mantienen a las cabras en sistemas de pastoreo extensivo. La brucelosis caprina es una de las limitaciones de la crianza de cabras, ya que afecta negativamente los parámetros de producción y más porque la brucelosis se puede transmitir al humano. Esto podría contrarrestar el impacto potencialmente positivo de las cabras en los modos de vida de la gente que se dedica a esta actividad.

En México, el control de la brucelosis se inició en 1971, sin embargo, sigue siendo endémica en la población de cabras. La brucelosis caprina es causada por *Brucella melitensis* y la transmisión se produce por contacto directo e indirecto con animales infectados o fomites contaminados. La infección puede inducir placentitis, lo que resulta en aborto en el último tercio de la gestación y también se asocia con los nacimientos prematuros y retención de placenta; mientras que en los machos causa orquitis. Las consecuencias tienen un impacto negativo en la productividad del rebaño y en el valor económico y el bienestar del animal. *B. melitensis* es la especie más patógena de las Brucellas en los seres humanos. Aunque la brucelosis raramente es una enfermedad mortal en humanos, quienes son huéspedes accidentales, puede ser muy debilitante y discapacitante. Un síntoma general de la brucelosis es la fiebre ondulante, pero las complicaciones como la artritis y la espondilitis son comunes.

Los principales objetivos de esta tesis fueron evaluar el impacto de la brucelosis en los pequeños productores de cabras y evaluar estrategias de control de la brucelosis para mejorar sus modos de vida. El enfoque de la investigación fue el de un estudio de caso con el fin de entender cómo se ha abordado el control de la brucelosis caprina. El estudio de caso se llevó a cabo en dos estados de la región del Bajío: Michoacán y Jalisco. Los dos estados comparten un área que es interesante, con respecto al control de la brucelosis - el comercio de cabras y productos caprinos es común entre las comunidades rurales de ambos estados y la aplicación de medidas de control de la brucelosis es diferente entre los dos estados. El estudio siguió el marco teórico "DEED", acrónimo de Descripción, Explicar, Explorar y Diseñar. Por lo tanto, en primer lugar se **describen** los antecedentes históricos de la crianza de cabras y el estado actual de la brucelosis en México (Capítulo 1). En el capítulo 2, utlizando el enfoque de

modos de vida, se **describen** los modos de vida de los pequeños productores de cabras en el contexto de los factores sociales y económicos, por ejemplo, la migración y las políticas neoliberales.

Dos encuestas, una con los pequeños productores caprinos (N = 46), y otra con los vecinos de los productores (N = 145), se llevaron a cabo en cuatro pueblos de Michoacán. La encuesta de los pequeños productores se utilizó para caracterizar los modos de vida de los productores de acuerdo a su estrato socioeconómico (pobre, medio y acomodados). En este estudio también se investigó cómo la caprinocultura es valorada en los hogares; esto incluye la identificación de las diferentes funciones de la crianza de cabras y de otras estrategias utlizadas por los pequeños productores.

El segundo estudio tuvo como objetivo conocer las percepciones de los vecinos de los pequeños productores. El capítulo 3 informa sobre los resultados de una encuesta epidemiológica que incluyó 1,713 cabras de 83 rebaños para **explicar** las diferencias de seroprevalencia y para identificar y cuantificar los factores de riesgo de la brucelosis. En el capítulo 4, las opciones para el control se analizaron en base a una combinación de modelos: (1) un modelo de transmisión de la brucelosis a nivel de pueblo (n = 1,000 cabezas), (2) un modelo de crecimiento a nivel de rebaño de pequeños pequeños productores (n = 23 cabezas) y (3) un análisis financiero de varios escenarios de control de la brucelosis. De esta manera, los resultados de epidemiología veterinaria se pusieron en contexto para evaluar la viabilidad de las estrategias de control: la vacunación, muestreo serológico y el sacrificio, una combinación de ambas vacunación y muestreo-sacrificio, y por último se evaluó el no control. En el capítulo 5, se **exploran** las opciones de control mas a fondo mediante la incorporación de las percepciones de los productores, quienes son influenciados por su marco de referencia (es decir, prácticas, conocimientos, intereses, creencias y experiencias). Las percepciones de los pequeños productores se evaluaron a través de métodos etnográficos y técnicas de participativas rurales. En el capítulo 6, se presenta un re**diseño** de la campaña de lucha contra la brucelosis en base a los resultados descritos en los capítulos 1 a 5.

Hay una historia relativamente larga, de cerca de 500 años, de crianza de cabras en la región. Los pequeños productores utilizan una serie de activos para involucrarse en la crianza de cabras. La crianza de cabras está enfocada a la leche; es una fuente de ingresos semanales, alimentos, seguros, créditos, y una razón para no tener que emigrar a los Estados Unidos. (Capítulo 2). Por otra parte, la crianza de cabras se valora como un aprendizaje para los hijos de los pequeños productores, y les da prestigio en los pueblos. En general, los pequeños productores tienen una alta estima entre sus vecinos, que se refieren a ellos como 'Gente de Trabajo' (capítulo 2).

Los pequeños productores de cabras tienen un amplio conocimiento de la crianza de cabras, saben aprovechar la vegetación nativa y los residuos agrícolas para alimentar a sus rebaños (Capítulo 2). El relativamente buen capital social de los pequeños productores les permite acceder a residuos de cultivos baratos y turnarse para pastorear los rebaños. Los hogares pobres tienen un promedio de 37 cabras, y la crianza de cabras es una de las principales estrategias de modos de vida. Los hogares del grupo medio y acomodados tienen una gama más amplia de actividades. El mercado de la leche de cabra es controlado por la industria de la cajeta, y los productores obtienen márgenes limitados. Los márgenes brutos en MX$ per cápita; de los pequeños productores pobres (media = 4,987, CI = 3,895 - 11,948) y medianos productores (media = 9,029, CI = 7,736 - 11,723), se encuentran debajo la línea de pobreza. Los productores, sin embargo, consideran que estan en mejores condiciones que los campesinos que no tienen cabras 'es mejor arrear que ser arreado' – nos contaron y es que las cabras son fuente de empleo y un ingreso económico semanal. Por otro lado, en sólo la mitad de los hogares de los pequeños productores, se consumen productos lácteos y la leche cruda se evita ya que es vista como una causa de "fiebre", relacionada con la brucelosis, también conocida como fiebre de Malta (en humanos). Los pequeños productores en general

no saben que la brucelosis y la fiebre de Malta son sinónimos, tampoco conocen los impactos económicos de la brucelosis (Capítulo 5).

La magnitud de la prevalencia de la brucelosis en el sitio del estudio se presenta en el capítulo 3. La prevalencia de brucelosis fue mayor en Jalisco (38%), que en Michoacán (11%). El análisis de regresión logística indicó que las cabras de Michoacán tienen menores probabilidades de ser seropositivas (OR = 0,32, IC del 95%: 0,21 a 0,48) que las cabras de Jalisco. Las cabras en sistemas de cero pastoreo tienen probabilidades más bajas de ser seropositivas que las cabras en los sistemas de pastoreo (OR = 0,22, IC del 95%: 0,09 a 0, 57). Las probabilidad de dar positivo es mayor cuando los pequeños productores compran las cabras de los revendedores (conocidos como birrieros) (OR = 1,82, IC del 95%: 1,15 a 2,87) en comparación con los pequeños productores que no lo hacen. Si las cabras se mantienen en corrales con baja densidad (0,002 a 0,22 cabra/m^2) tienen menor probabilidad de dar positivo (OR = 0,4, IC 95% 0,3-0,8) que cuando estan en corrales de mayor densidad (0,23 a 1 de cabra /m^2). Si gallinas y pollos tienen acceso a los corrales, se reduce la probabilidad de dar positivo (OR = 0,52, IC del 95% desde 0,33 hasta 0,83), que en aquellos corrales donde las aves no tienen acceso. La desinfección regular del corral reduce la probabilida de dar positivo (OR = 0,66, IC 95% 0,44-0,99) en comparación a donde la desinfección no es regular. Se concluyó que la baja prevalencia en Michoacán, demuestra que la campaña de control de brucelosis en este estado fue más eficaz en la reducción de la seropositividad que la campaña en Jalisco.

En Michoacán la adopción de la campaña fue casi completa porque el servicio era gratuito, mientras que la vacunación en Jalisco no se adoptó a fondo debido a que los pequeños productores tuvieron que asumir parte del costo de la vacunación y porque había una falta de veterinarios que ofrecieran los servicios (capítulo 5). Los pequeños productores no son conscientes de la importancia del control de la brucelosis y no están preparados para solventar los altos costos. En el capítulo 4 se presenta un análisis financiero. El valor actual neto (VAN) de la utilización de la vacunación por cabra fue de 3.2 pesos (MX $) y la relación beneficio / costo fue de 3,8. El VAN para la población de cabra de la región fue de 123,078 pesos mexicanos (MX$), aproximadamente 10,000 dólares estadounidenses en cinco años. Por lo tanto, el impacto de la vacunación con Rev 1 en la reducción de la seroprevalencia se muestra ligeramente positiva a nivel regional. Sin embargo, se prevé que la prevalencia de la brucelosis se mantendrá relativamente alta: alrededor del 12%. Con los escenarios de control con pruebas y sacrificio se estima que reducir la prevalencia de la brucelosis a menos del 3%, coincide con un VAN negativo en el rango de -676,407 a - 1.226.085 (MX$). En conclusión: una campaña de lucha contra la brucelosis basada en la vacunación con una cobertura total es económicamente rentable para el sector de la leche de cabra de la región. Sin embargo, si se decidiera hacer pruebas y sacrificio a fin de reducir la prevalencia a niveles por debajo del 3%, los pequeños productores no podrían solventar los costos. Actualmente, no se realiza sacrificio de animales infectados sospechosos y no existe una infraestructura adecuada para el sacrificio. Asimismo, debe asegurarse que las cabras que salen seropositivas no se vendan a otros pequeños productores. Por otra parte, los pequeños productores perciben que las medidas de control de la brucelosis causan pérdidas como el aborto debido a la vacunación e infecciones del oído causadas por los aretes. En el capítulo 5 se cuestiona la idea de que el control de la brucelosis se debe solamente a la falta de conciencia y participación de los pequeños productores en las medidas de control, y se argumenta que hay una falta de comunicación en ambos sentidos: a los pequeños productores no se les informa sobre qué es exactamente la brucelosis, mientras que las políticas se implementan sin conocer a fondo las percepciones de los pequeños productores y de las prácticas de manejo de cabras en la región.

En el capítulo 6, la discusión general, se plantean las siguientes preguntas: ¿Es la crianza de cabras un camino para salir de la pobreza? ¿Es la brucelosis una limitante para aliviar la pobreza? ¿Cómo se puede controlar la brucelosis? Con base a los modos de vida, se demuestra que el papel las cabras para los pequeños productores pobres y medios es ambivalente,

por un lado, la crianza de cabras los hace menos vulnerables, por otro lado el bajo precio de la leche de cabra y la presencia de brucellosis en los rebaños de cabras, pone sus modos de vida en una posición vulnerable. Hay amplias recomendaciones para el control de la brucelosis, pero éstas no son aplicables plenamente en México, como ocurre también en otros países del Sur Global. Tres paradigmas en relación a la lucha contra la brucelosis son puestos en tela de juicio. En primer lugar, *la vacunación es barata*, de hecho, los costos de vacunación son altos para los pequeños productores y para el Estado, en parte debido a que la vacunación tiene que llevarse a cabo por veterinarios autorizados. En segundo lugar, *sólo los pequeños productores necesitan ser entrenados para controlar la brucelosis*, de hecho, los pequeños productores carecen de conocimiento acerca de la brucelosis, pero los veterinarios y las autoridades de salud saben muy poco acerca del manejo de cabras en la región. Por lo tanto, todas las partes interesadas necesitan aprender acerca de la brucelosis y el manejo de cabras a fin de lograr comprensión mutua. En tercer lugar, *'las pruebas y sacrificio' están fuera del alcance en el Sur Global*. De hecho, los costos para el sacrificio son altos; sin embargo, la erradicación de la brucelosis a través de pruebas y sacrificio debe de ser posible especialmente si se puede crear un mercado de nicho para los productos lácteos de cabra. El control de la brucelosis es una oportunidad de 1) acceder a un mejor mercado, 2) evitar la migración al norte (a los Estados Unidos), y 3) mejorar la salud y el bienestar de los pequeños productores, es decir, de sus modos de vida. El control de la brucelosis es una oportunidad para que los pequeños productores de cabra mejoren sus modos de vida.

La política para el control de la brucelosis debe ser rediseñada. Hay cuatro factores importantes a considerar en el diseño de una nueva política; en primer lugar, una indemnización completa por las pérdidas cuando se planeen pruebas y sacrificio de ganado; segundo, el reconocimiento y la integración de los conocimientos y experiencia de los pequeños productores en el diseño de las intervenciones de control; tercero, la difusión de conocimientos acerca de la brucelosis, su prevención, el impacto en la salud humana y de cabras y en la producción caprina; cuarto, una planificación regional es indispensable para tener éxito.

ACKNOWLEDGEMENTS

I dreamed many times about this moment, I mean, about right now, writing this lines. It was a tough process to reach this point, many people helped me, in different ways to achieve it, I could not have made it myself.

I would like to start by thanking the goat farmers who took part in this research and shared with me their knowledge, time and experiences. You were very kind to me during the field work, you invited me to have lunch and supper a number of times and offered me to stay over night at your homes:

Gracias a todos los chiveros y chiveras de San José de Vargas, Tinaja de Vargas, Las Fuentes, Los Charcos, Cieneguitas, La Labor Vieja y Barranca el Aguacate. En especial quiero agradecer a las familias de Don Luis Valadéz, Pancho Magdaleno, Martín Magdaleno, José Alvarado, Ignacio Tinajero, Felipe Barriga, Salvador Barriga, José Pimentel, Ignacio Pimentel, Martín Airas, David Arias, Ramón Flores, Carlos Flores, Gerardo Flores y Jesús Flores, gracias por su hospitalidad y su gran ayuda durante el trabajo de campo. Gracias Martín Arias y Felipe Barriga por conseguir datos claves para el estudio.

I would like to thank my promotor Prof. Dr. Akke van der Zjipp and co-promotors Dr. Klaas Frankena and Dr. Henk Udo for accepting me as PhD student and guiding me all of these years. Akke I appreciate all the patience you had with me and your kind hospitality, my family had supper a number of times at your beautiful house, first in Ede and lately in Wageningen. You gave direction to the research and guided the thesis to a good end. Klaas thanks for teaching me how to write concisely and precisely, I appreciate that you took the time to scrutinize all the statistical analyses and manuscripts, especially when referring to quantitative veterinary epidemiology. Anyway, 'R you ready to keep collaborating?' Henk, I went through tough moments and you were there to support me from the very beginning, thank you for listening and for guiding me all the way through. I admire your courage in life, patience and good humour. Thank you for teaching me to write with coherence and meaning. Akke, Klaas and Henk many thanks.

I also want to thank Dr. Nícola Keilbach Baer, muchas gracias Nícola, la calidad de este trabajo no sería lo que es ahora sin tu gran ayuda en el trabajo de campo y en el análisis de los modos de vida. Gracias por recibirme en el Colegio de Michoacán, donde pude tomar un excelente curso que fué clave para poder entender los modos de vida rurales.

When this idea of a PhD was developing, Prof. Dr. Anne Valle-Zárate hosted me at the Institut für Tierproduktion in den Tropen und Subtropen, Hohenheim University. I am grateful to Prof. Dr. Valle-Zárate and Dr. Marianna Siegmund-Schultze who gave their input and opportunities to discuss my ideas. I am also thankful to Prof. Dr. Gall and Prof. Dr. Kaufmann for their advice too. Nils, André, Tee and Mingrelia thank you for your help and friendship while in Hohenheim. I also had the privilege to follow an excellent course at Hohenheim University, on participatory methods for rural development, which was key in the PhD study, Prof. Dr. Andreas Neef, course coordinator, thank you Andreas.

To all the staff at Animal Production Systems, thank you for your words of encouragement, especially when I was approaching the deadlines. Fokje, thanks for your help in designing the cover, Theo, thanks for your help when needed on IT. Prof. Dr. Mike Grossman, thank you very much for the nice courses you taught, they are fun and very useful. Thank you as well for suggesting an improvement in the thesis title. Akke (Kok) thank you so much for translating the summary in Dutch, I appreciate it very much. I also want to thank the chair of the group Prof. Dr. Imke de Boer. Imke, I felt your sincere happiness when the thesis was finally accepted, you cared about my progress and you made sure I had place to work.

Albart Coster gracias por enseñarme R y LaTeX. Dr. Karen Eilers, gracias por visitarme y darme tus opiniones durante el trabajo de campo. Ymkje hartelijk bedankt voor jouw hulp in deze tijd. Chizu thank you for your help in chapter 2. Ansa thanks for sharing the LaTeX code to compile this thesis.

Ik wil ook het personeel van de Zwanenridders bedanken: de juffen, Bernadet, Anja, Riane, Reini, Wieke, Urszula, Elly, Iris, Heidi, meester Wolter, en de directeur, meester Herman. Bedankt voor jullie aandacht en steun voor onze kinderen.

Aan de vele vrienden in Nederland, we hebben genoten van jullie gastvrijheid en vriendschap, families van Steenbergen, Dina, familie Sato, familie van Buiten en familie Gamblin. Jim thank you so much for your friendship and for sharing your artwork with us.

To the community from the International Student Chaplancy, Josine, Eef, Arnold, Jolande and Alexandre, thank you very much for your friendship and spiritual support during this time. Also to the community of Johannes de Doper, pastor Henri ten Haven, familie Merino Klassen, Annie Keukens en Jeroen en Nicole van Rijn, dank je wel.

To Prof. Dr. Jonathan Rushton and his group at the Royal Veterinary College, Jonathan, muchas gracias por darme la oportunidad de estar un tiempo en tu grupo, ayudarme a recobrar la confianza en mi mismo y por toda tu ayuda. Mieghan, Wendy and Mahmout, I enjoyed the interesting discussions we had about brucellosis. Mieghan thank you very much for your co-authoring chapter 4, core of this thesis. Joshua, it was very nice meeting you and I admire your patience. To the many colleagues of Jonathan at the Royal Veterinary College, I had a great time in the UK.

Denise Magendans and Marianne Bruining, at WIAS, thank you very much for your help.

Dr. Anne Pearson, gracias Anne por tu gran ayuda. Thank you for your great help with the English and for commenting on various thesis chapters.

Martha and Chuck, *mis compadres*, thank you very much for coming all the way from the US to visit us twice and for your kind hospitality at your place, I do not have words to thank you.

Familie Duijzer, ik heb geen woorden om jullie te bedanken voor alle steun door de jaren heen. Dank je wel voor jullie gastvrijheid, oprechte vriendschap, vrijgevigheid en jullie steun in moeilijke tijden. Hartelijk dank. Gijsbert, Margreet, Dirk, Bea, Wolda en kinderen en kleinkinderen, dank jullie zeer.

Quiero agradecer a mis suegros, Dr. Francisco y Dra. Chayito, por su apoyo durante estos años, muchas gracias, no habría sido posible sin su apoyo. Les admiro su generosidad y valor para salir adelante.

Mamá gracias por tus palabras de ánimo, por tu optimismo y consejos para salir a flote. Sabía que podía oir palabras de ánimo cuando te llamaba. A mis hermanos gracias a los tres por ser ejemplo para mí. Andrés que bueno saber que tu habías podido culminar y de que manera con un premio a la mejor tesis en etnografía del INBA. Lupita gracias por ser ejemplo de trabajo arduo, disciplina y amor por tus hijos, por tu hogar. Sin tu ayuda, viajar tantas veces, de aquí para allá, hubiera sido casi imposible. Bety admiro tu determinación, valor para sobreponerte y tu entrega en el trabajo, gracias.

A mis amigos veterinarios Pancho López y Miguel Villalba muchas gracias por su ayuda cuando preparaba este último viaje a los Países Bajos, sabía que contaba con ustedes.

Antonio y Cristóbal gracias por estar aquí, no podría estar mas feliz, me inspiran a ser mejor persona, son el tesoro mas preciado que tengo. Amada Eliza, no estaría aquí sino fuera por que decidimos este rumbo juntos y por que me has ayudado muchísimo, te admiro, te quiero, gracias.

ABOUT THE AUTHOR

David grew up in Mexico City, he graduated as veterinarian in 1996 at the National Autonomous University of Mexico (UNAM). While he was still a student, David started to work as a volunteer to treat and prevent ailments in working equids in Mexico at the mobile clinic unit for working equids. There he learned about animal welfare, animal health and the role of equids for the livelihoods of farmers. His bachelor thesis was awarded with the medal Gustavo Baz Prada. In 1997 he was invited to work for one year at the Donkey Sanctuary Hospital, Devon, England. Three years later, he became one of the senior veterinarians at the mobile clinics in México. David worked more than ten years as a clinician at the mobile clinic project. He also worked part time as a consultant and clinician with small dairy cattle holders of Guerrero, Mexico.

In 2003, he obtained a scholarship from the National Council of Science and Technology of Mexico (CONACYT) to pursue graduate studies at the University of Wageningen in the Netherlands, where he wrote two MSc theses, one in the group Animal Production Systems and the second in the group of Quantitative Veterinary Epidemiology.

In 2007, CONACYT and the Alpha and Omega foundation from the Netherlands sponsored his PhD study at the University of Wageningen. The results of his research have been disseminated at international conferences and in international peer reviewed journals. He plans to continue doing applied research on livelihoods, animal health and epidemiology to improve the livelihoods of smallholder farmers.

PUBLICATIONS

PEER REVIEWED

- **Oseguera Montiel, D.**, Keilbach Baer, N.M., van der Zijpp, A., Sato, C. and Udo, H.,'It is better to herd than be herded'. Making a living with goats in the Bajío region, Mexico. (2014) *Pastoralism: Research, Policy and Practice* 4: 1-18.
- **Oseguera Montiel, D.**, Frankena, K., Udo, H., Keilbach Baer, M.N., and van der Zijpp A (2013). Prevalence and risk factors for brucellosis in goats in areas of Mexico with and without brucellosis control campaign. *Tropical Animal Health and Production*, 45: 1383-1389.
- **Oseguera Montiel, D.**, Mieghan, B., Frankena, K., Udo, H., van der Zijpp, A. and Rushton, J. (Under review) Financial analysis of brucellosis control in small-scale goat farming in the Bajío region, Mexico. Submitted to Preventive Veterinary Medicine.
- **Oseguera Montiel, D.**, Udo, H., Frankena, K., van der Zijpp, A. *'La fiebre Malta'*: an interface of farmers and caprine brucellosis control policies in the Bajío region, Mexico. Submitted to Zoonoses and Public Health.
- **Oseguera Montiel, D.** (2006) La relevancia de los animales de trabajo en los sistemas agrícolas: Un estudio de caso en Chiapas. *Anuario de estudios indígenas XI*. Universidad Autónoma de Chiapas, Instituto de Estudios Indígenas, pp 143–165.

ABSTRACTS IN SCIENTIFIC MEETINGS

- **Oseguera Montiel, D**, Keilbach Baer, N., Udo, H., Frankena, K., y van der Zijpp, A. Prospects and Constraints for small-scale goat husbandry systems: A case study in the Bajío region, Mexico. *Wageningen Institution of Animal Science (WIAS Science Day).* Wageningen, the Netherlands, February 28^{th}, 2013.
- **Oseguera Montiel, D** y Keilbach Baer, N.M, Modos de vida campesinos bajo la golbalización: los chiveros de Michoacán y Jalisco. 8^{o} *Congreso de la Asociación Mexicana de Estudios Rurales: Campesinos y procesos rurales.* Puebla, Puebla, México, 24–27 Mayo, 2011.
- **Oseguera Montiel, D**, Frankena, K., Udo, H. y van der Zijpp, A. Control of brucellosis in Mexican goat farming: Epidemiological evidence in livelihoods context 13^{th} *Congress of the Association of the Tropical Veterinary Medicine (AITVM)*. Bangkok, Thailand August 23–26^{th}, 2010.
- **Oseguera Montiel, D** y Keilbach Baer, N.M,. (2009) Hopes and Threats for Successful Rural Livelihoods: The Role of Social Capital among Small-scale Goat Farmers in Central Mexico. At the Tropentag 2009: Biophysical and socio-economic frame conditions for the sustainable management of natural resources, Hamburg, Germany, October 2009.
- **Oseguera Montiel D**, Udo, H., Keilbach Baer, M.N., van der Zijpp, A. (2008) Small-scale goat farming systems in the Ciénega region of Mexico: constraints and prospects for brucellosis control. At 9^{th} Congress International Goat Association, Querétaro, México, August 31^{st} to September 4^{th} 2008.
- **Oseguera Montiel, D**, Udo H.M.J. y Steenstra, F.A. 4^{th} *International Colloquium on Working Equines* The role of animal power in agricultural systems: A case study in Chiapas, Mexico. Adis Ababa, Ethiopia, November, 2006.

PHD EDUCATION PLAN

With the educational actvities listed below the PhD candidate has complied with the educational requirements set by the graduate school Wageningen Institute of Animal Science (WIAS) at Wageningen University, which comprises a minimum of 30 ECTS, which equals a workload of 21 weeks. Each ECTS (An European Credit Transfer and Accumulation System) equals a workload of 28 hours.

BASIC PACKAGE (3.0 ETCS)

- WIAS Introduction Course
- Biology underpinning animal sciences: broaden your horizon

SCIENTIFIC EXPOSURE (9.2 ETCS)

- Three international conferences: (1) 9^{th} International Conference on Goats, (2) Tropentag 2009, (3) 13^{th} Association of Institutions for Tropical Veterinary Medicine
- Four seminars
- Five oral/poster presentations at international conferences

IN-DEPTH STUDIES (11.0 ETCS)

- Participatory methods for rural development, Hohenheim, Germany
- Scenario development, Wageningen, the Netherlands
- Rural history of Mexico, Colegio de Michoacán, Zamora, Michoacán
- Design of animal experiments, Wageningen, the Netherlands
- Introduction to R for statistical analysis, Wageningen, the Netherlands
- Getting started in AS-Reml, Wageningen, the Netherlands

PROFESSIONAL SKILLS SUPPORT COURSES (3.0 ETCS)

- Techniques for Scientific Writing, Wageningen, the Netherlands
- Writing Research Grant Proposals, Wageningen, the Netherlands

RESEARCH SKILLS TRAINING (6.0 ETCS)

- Preparing own PhD research proposal

DIDACTIC SKILLS TRAINING (0.6 ETCS)

- Tutoring: Integrated course Ruminants, Wageningen University, the Netherlands

Total ECTS 33.0

COLOPHON

This research was generously funded by the foundation Alfa en Omega in the Netherlands and by the National Council for Science and Technology in Mexico.
This thesis was written with LaTeX.
Cover design by Fokje Steenstra and David Oseguera Montiel
Photos in Figures 2.4 and 2.9 by Nícola Maria Keilbach Baer. The rest of the photos by David Oseguera Montiel.
This thesis was printed by GVO drukkers & vormgevers B.V., Ede, the Netherlands.