

Promotion and adoption of silage technologies in drought-constrained areas of Honduras

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Abstract

In the tropics, environmental constraints such as drought limit forage supply, and thus livestock production and competitiveness of livestock systems. Forage conservation technologies could mitigate the dry season feed problems but their adoption in smallholder systems has so far been low. The present work, carried out in Honduras, examined factors that influenced the uptake of promoted silage technologies in order to derive suggestions for further R&D interventions. A total of about 250 farmers participated in training sessions and field days. Information was gathered using interviews with 222 participants.

Maize and sorghum were the most common crops (>60%) used for silage making, with grass being ensiled to a limited extent. All silo types were used (mean of ≈ 2 silos/farm) with earth and heap silos being most widely accepted. Financial and farm resources, farmers' education, extension continuity and intensity, and the presence of key innovators, motivated farmer groups and favourable milk market conditions contributed to increased adoption. The most common reasons for non-adoption were the lack of a chopper (small and medium farms), silage too expensive (medium farms) and silage not needed (large farms). Extension strategies need to be

adapted to specific conditions to efficiently support a sustainable forage and livestock development process. Continuous promotion can lead to significant and sustained adoption with subsequent potential benefits for more smallholders via increased locally available know-how and easier access to machinery and markets.

Introduction

In areas with a long dry season, tropical pastures rarely provide sufficient year-round feed of reasonable quality to match the nutritional demands of livestock and support satisfactory livestock production and reproduction (Suttie 2000). Conserving forage as silage is an option to alleviate feed constraints and maintain animal productivity during dry periods. However, in spite of numerous research and development (R&D) efforts, adoption of silage technologies has been low in the tropics and subtropics, especially by resource-poor smallholders. Reasons have been suggested as mainly lack of know-how, lack of financial means and insufficient benefits and returns on investment (Mannetje 2000).

R&D needs to develop strategies to enhance adoption of forage conservation technologies by the poor, thus enabling them to increase animal production and enter expanding markets for livestock products (Delgado *et al.* 1999). Technical support and better access to markets are often required, as well as the fostering of human and social capital through participation of farmers in the selection and adaptation of inexpensive and efficient technologies (Bruinsma 2003; Chipeta *et al.* 2003).

During a research project conducted by CIAT (Centro Internacional de Agricultura Tropical) and the Honduran Institute for Agricultural Research and Extension (Dirección de Ciencia y Tecnología Agropecuaria, DICTA) in 2004 and 2005, training sessions for farmers were held in different drought-constrained areas of Honduras

(Reiber *et al.* 2007a). The overall aim was to increase adoption of silage technologies among smallholders. Two extension strategies, adapted to different adoption stages and ‘knowledge groups’, were distinguished: (a) ‘promotion of innovation’ (PI) was applied with groups of smallholders in locations where silage was not used or known, in order to test and adapt low-cost silage technologies (*e.g.* little bag silage); and (b) ‘promotion of adoption’ (PA) was applied in locations where at least one innovative farmer had some experience with silage prior to commencement of the project. PA, in which prototype farmers were involved (farmer-to-farmer approach), served to investigate the effect of longer-term promotional activities on the adoption and diffusion of silage technology.

In an endeavour to derive recommendations for further R&D interventions, this study sought to identify factors that influence the adoption or rejection and diffusion of silage making, considering: (a) technological aspects (adopted silo and silage types); (b) farmer criteria (reasons for

adoption or rejection); (c) farm factors (farm size and intensification level); (d) local conditions (milk market and farmer groups); and (e) extension strategies (PI and PA).

Materials and methods

Climatic characterisation of research areas in Honduras

The study was carried out in the departments of Yoro, Olancho, El Paraíso, Lempira and Intibucá. Average annual precipitation ranges from about 900 mm in El Paraíso to about 1200 mm in Yoro, with considerable year-to-year variation. In Yoro, for example, it ranged from about 800 mm in 2002 to about 1600 mm in 2005 and 2006, and in El Paraíso from 640 mm in 2001 to 1170 mm in 2005 (unpublished data from the National Meteorological Service of Honduras). Dry season length usually ranges from about 4.5 months (January to mid-May) in Olancho to about 7 months

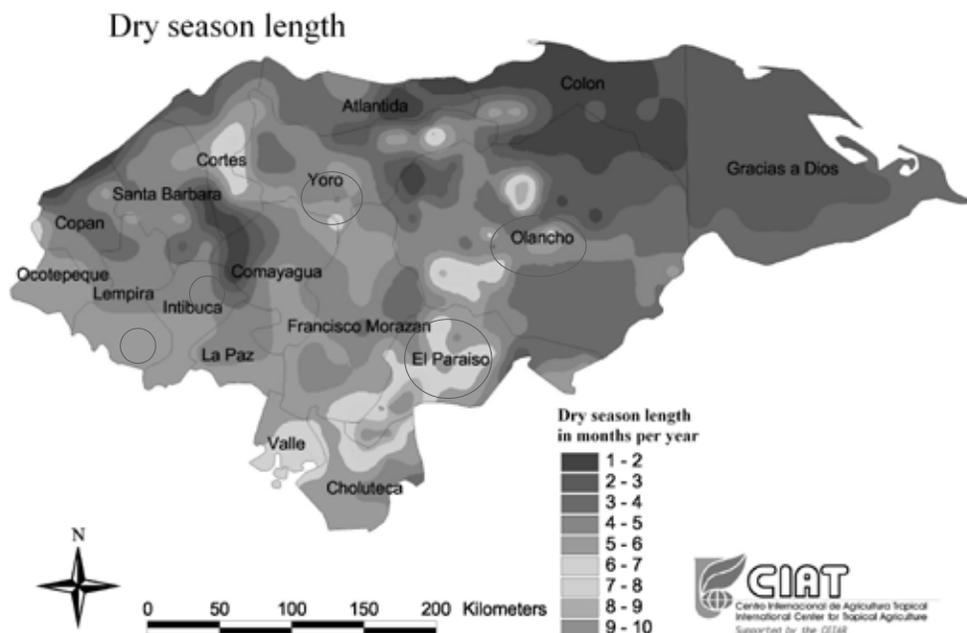


Figure 1. Dry season length and research areas in Honduras (Lentés *et al.* 2010).

(mid-October to mid-May) in Alauca (El Paraíso) (Figure 1). Average temperature increases from about 19–24°C in the coldest month (January) to 27–28°C in the hottest months (April and May). Mean annual temperature varies up to 1.6°C between years.

Characterisation and classification of research and extension groups

Farmer groups and/or individual farmers were invited to participate in training sessions and/or field days conducted by CIAT and local partners. Adoption stages and knowledge about silage differed amongst research locations and accordingly two extension strategies, namely promotion of innovation (PI) and promotion of adoption (PA), were applied.

The main differences between target groups and the extension strategies employed are presented in Table 1 for a total of 13 case studies. The overall principles of extension were based on a problem-solving and demand-driven approach, including demonstrations of different technologies and technological adaptations, learning-by-doing, and farmer-to-farmer promotion. Training exercises included both theoretical and practical components. In the theoretical part, after an introductory assessment of farmers' problems and goals, the training focused on forage and livestock production issues, particularly forage conservation (objectives, advantages and disadvantages),

and the technical aspects of silage making (*e.g.* optimal cutting time, important steps, forages to conserve, additives, characteristics of a good silage and silo types). Besides heap and earth silos, little bag silage (LBS) was promoted as a low-cost alternative. Illustrated information leaflets with instructions and recommendations were distributed (Reiber *et al.* 2007b).

Table 2 presents the case studies, grouped into the 2 extension strategies and 3 extension intensities. The latter grouping reflects the number of training sessions, the presence of a technician to directly support farmers, and the number of farmers involved, whereas the grouping in extension strategies implies the time period of extension.

Training sessions were carried out by project staff except for case 7 representing the NITs (Núcleos de Intercambio Tecnológico). NITs were established and supported by the 'Fondo Ganadero'; the case includes 8 farmer groups of 5 smallholders each, who were trained and supported in silage production using a heap silo. Farmers from Candelaria (case study 13) were supported by local technicians with occasional support from CIAT.

Data collection

In total, 259 farmers participated in training sessions. Basic farm data (*e.g.* farm size and number of animals) were gathered from 222 partici-

Table 1. Characteristics of target groups and strategies employed.

| | Promotion of innovation (PI) | Promotion of adoption (PA) |
|-----------------------------------|--|---|
| Desired effect | Technology uptake and adaptation | Wider impact, diffusion |
| Characterisation of target groups | | |
| Pilot farms with silage | No | Yes |
| Awareness of silage technology | No | Yes |
| Silage technology know-how | No | No |
| Strategies applied | | |
| Target groups | Groups of smallholders | Individual farmers and groups |
| Type of knowledge transfer | Training sessions | Demonstrations, field days, farmer-to-farmer visits |
| Use of little bag silage (LBS) | As entry point | As a training tool and option for smallholders |
| Transfer agents | Technicians, extension personnel and researchers | Technicians, extension personnel, researchers and farmers |
| Number of case studies | 7 | 6 |

Table 2. Characterisation of case studies.

| No. of case study | Municipality, department | Extension strategy ¹ | Extension intensity | No. of participating farmers | No. of training sessions ² | Technical assistance | Promoters/ collaborators ³ |
|-------------------|-----------------------------------|---------------------------------|---------------------|------------------------------|---------------------------------------|----------------------|---------------------------------------|
| 1 | San Pedro de Catacamas, Olancho | PI | Low | 18 | 1 | No | CIAT/UNA |
| 2 | San Francisco de Becerra, Olancho | PI | Low | 21 | 1 | No | CIAT/ DICTA |
| 3 | San Francisco de la Paz, Olancho | PI | Low | 17 | 1 | No | CIAT/ DICTA |
| 4 | Jesús de Otoro, Intibucá | PI | Medium | 8 | 2 | Partly | CIAT/ FIPAH (CIAL) |
| 5 | Las Vegas, Yoro | PI | Medium | 14 | 2 | No | CIAT/Ayuda en Acción |
| 6 | Alauca, El Paraíso | PI | Medium | 10 | 2 | Partly | CIAT/ DICTA |
| 7 | Jamastrán-2 (NITs), El Paraíso | PI | Medium | 40 | 2 | Partly | Fondo Ganadero |
| 8 | Jamastrán-1, El Paraíso | PA | Medium | 24 | 3 | Partly | CIAT/ DICTA |
| 9 | Victoria, Yoro | PA | High | 29 | >3 | Yes | CIAT/ DICTA |
| 10 | Sulaco, Yoro | PA | High | 19 | >3 | Yes | CIAT/ DICTA |
| 11 | Yorito, Yoro | PA | High | 23 | >3 | Yes | CIAT/ DICTA |
| 12 | Yoro, Yoro | PA | High | 21 | 3 | Yes | CIAT/ DICTA |
| 13 | Candelaria, Lempira | PA | High | 15 | 2 | Yes | FAO/CIAT/ ITC |

¹ PI: Promotion of innovation; PA: promotion of adoption.

² Includes field days.

³UNA: Universidad Nacional de Agricultura (National Agricultural University); ITC: Instituto Técnico Comunitario de Candelaria (Public Technical Institute of Candelaria); FIPAH: Fundación para la Investigación Participativa con Agricultores de Honduras (Foundation for Participatory Research with Honduran Farmers); CIAL: Comité de Investigación Agrícola Local (Local Agricultural Research Committee); CIAT: Centro Internacional de Agricultura Tropical (International Center for Tropical Agriculture); DICTA: Dirección de Ciencia y Tecnología Agropecuaria; and FAO: Food and Agriculture Organization of the United Nations.

pants (86%). In a continuous process, innovation, adoption and diffusion processes were monitored. Towards the end of the research study, structured interviews were conducted with trained farmers to assess adoption factors including farmers' perceptions. Semi-structured interviews with prototype farmers, group leaders and extension personnel/technicians were used to derive information on the local adoption status, technological potential and constraints. Silage fermentation quality was assessed on 14 farms, by evaluation of spoilage losses and organoleptic characteristics (smell, colour and texture).

Grouping of farmers and data analysis

Farmers were classified according to their herd size into small (1–20 head of cattle; 64 farmers), medium (21–50 head; 69 farmers), large (51–100 head; 58 farmers) and very large (>100 head; 31 farmers) farmers. A further grouping was made into silage adopters (farmers who had

made silage at least once and intended to re-use/repeat the practice), non-adopters, potential adopters (farmers who reliably intended to adopt) and rejecters (farmers who made silage at least once but decided to reject it). In the comparative analysis of adopters and non-adopters, rejecters were considered as non-adopters and potential adopters as adopters.

Methods applied for the comparative analysis of grouped farms included descriptive statistics (averages, standard deviations and frequencies), linear regression and non-parametric tests (Mann-Whitney test) for the screening of differences between groups.

Results

Traditionally, farmers have used a range of dry season feeding strategies for livestock. The most common strategy, practised by about 85% of interviewed farmers, was to graze down natural and/or sown pastures, and then to feed

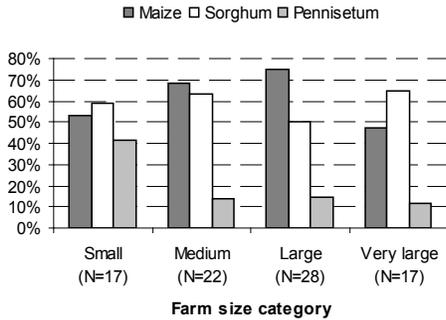


Figure 2. Forages used for silage in different farm size categories.

maize crop residues. About 75% used commercial concentrates, mainly as supplements to lactating cows, while about 72% used small areas of cut-and-carry forages, mainly grass (*Pennisetum* spp.) and sugarcane. About 20% of participants fed grass hay, usually *Brachiaria* spp., as a supplement mainly to animals other than lactating cows. Farmers with limited availability of forage often rented land with crop residues (usually maize stover) or utilised nearby hillside areas.

Adopted ensiling procedures and methods

Across all locations, the typical ensiling process was as follows: forage was cut with machetes, usually at the doughy stage of maturation for maize and sorghum; the cut forage was brought to the silo where it was chopped using motor-driven choppers (manual chopping was rarely practised); forage was compacted by rolling a water-filled barrel over the bulk or, if available, by a car; and molasses was added, mainly for forages other than maize and sorghum.

Ensiled forages. While silage was made almost exclusively from maize in 2004, 3 years later about 49% of the silage adopters ensiled at least 2 different crops with an increasing share of sorghum [66% ensiling maize, 61% ensiling sorghum, 20% cut-and-carry grasses (*Pennisetum* spp. 'King Grass' or 'Camerún'), 6% sugarcane, 4% *Brachiaria brizantha* cv. Toledo and 4% cowpea (*Vigna unguiculata*)]. Small-scale farmers ensiled relatively more cut-and-carry grass than larger-scale farmers (Figure 2).

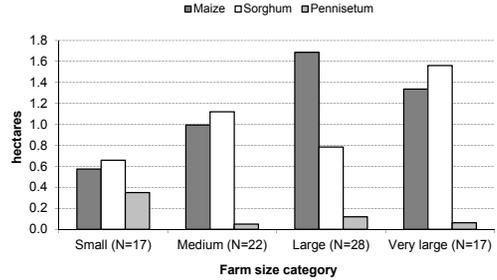


Figure 3. Area dedicated to silage production in different farm size categories.

In 2007, the average area per farm dedicated to silage production was 2.3 ha, with 1.7 ha, 2.3 ha, 2.7 ha and 3.0 ha for small, medium, large and very large farms, respectively. The average areas of maize, sorghum and cut-and-carry grasses for silage were 1.2, 1.0 and 0.1 ha, respectively. Small, medium and very large farms dedicated a larger area to sorghum than to maize, whereas on large farms the area of maize grown was more than twice the area of sorghum (Figure 3).

Both maize and sorghum silage were considered by farmers as quality silages which were usually fed to crossbred dairy cows. The preference for maize and sorghum was evenly distributed among farmers who had experience with silage from both crops. Maize silage was often preferred to sorghum silage because of higher yield per unit area in a single cut plus higher palatability and nutritional value. Moreover, farmers considered maize silage produced fatter cows, higher milk production and a higher milk fat content. On the other hand, some preferred to grow sorghum for silage as it can give 2 or even 3 cuts and thus a higher total yield per unit area and year, which reduced costs. Sorghum was also better adapted to poor soils and drought. Many farmers from the Yoro area cultivated maize in the early planting season (*primera*) and sorghum in the following *postrera* season. Sorghum sown in September could still be cut once or twice for silage with subsequent regrowth being grazed, cut for feeding fresh or dried. Grain sorghum, similar to maize, was generally preferred to forage sorghum, owing to a faster harvesting and chopping

procedure, higher perceived nutritive value and adaptability to soil and climatic conditions.

With respect to silage fermentation, there was generally no problem with maize or sorghum even without any additive. In contrast, silage made from grasses, such as *Pennisetum purpureum* and *Brachiaria* spp., frequently showed fermentation problems, which were attributed to inappropriate ensiling management, in particular the high moisture content in the silos (grasses were often ensiled without pre-wilting) in combination with insufficient addition of molasses (less than the recommended 5%). Malfermentation led to losses and affected nutritional value and palatability. In contrast to maize and sorghum silage, farmers did not observe any effect on milk production of cows fed with silages made from cut-and-carry grasses. Therefore, grass silages, similar to hay made from pastures, were perceived as feed for maintenance rather than for milk production. When ensiled in mixture with maize or sorghum, grasses and/or legumes were reported by some farmers to have acceptable quality.

Adopted silo types. According to location, preferences for specific silo types evolved (Figure 4), mainly driven by availability of resources and examples of neighbouring innovators. In Yorito, all farmers copied a costly bunker silo built of bricks and mostly with a roof as on a prototype farm. Bunker silos were usually 7–10 m long, 4–5 m wide and about 2 m high. Capacity ranged from 28 to 50 tonnes (based on an estimated silage density of 500 kg/m³).

Heap silos were the main silo type used by silage novices in Yoro, Olancho and Jamastrán (El Paraíso). It was considered as ‘silo for the poor’, since it did not require large initial investments in infrastructure. Moreover, it was flexible in size and location, and the bulk could be compacted by car, which was not possible with the closed bunker silos used in Yorito. The earth silo had earth walls and was usually below ground level. In Candelaria, earth pits were used, while in Olancho, Victoria, Sulaco and El Paraíso, farmers preferred excavated slopes. Their open front facilitated both compaction and silage extraction. Heap and earth silos varied in size from small (about 4 m³) to very large (about 150 m³).

Little bag silage (LBS) proved useful as a learning tool and as an adaptable prototype for silage novices. It enabled the ensiling of small quantities and had lesser spoilage losses during feed-out. It was often used in addition to other silo types to (a) make use of surplus forage that did not fit in the other silo, (b) make special silages from forage legumes (*Cratylia argentea* and cowpea) in mixture with maize or sorghum and (c) use the paid labour force to capacity. However, only about 5% of the farmers adopted LBS. Reasons included high spoilage losses owing to perforation of plastic sheeting caused mainly by mice. After having tested LBS, many farmers used other low-cost silo types for larger quantities such as heap and earth silos.

The share of adopted low-cost silos such as heap and earth silos increased with decreasing farm size, whereas the share of cost-intensive bunker silos decreased (Figure 5). However, this

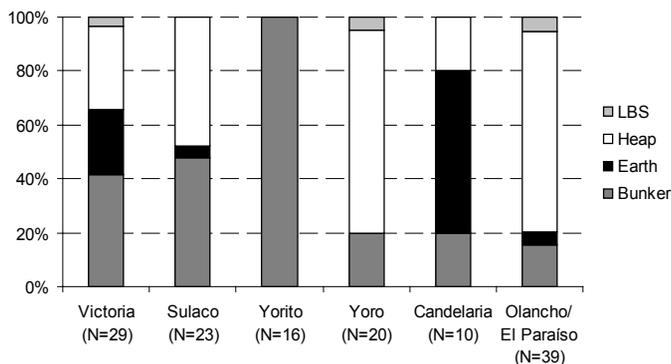


Figure 4. Adoption of silo types in the different locations.

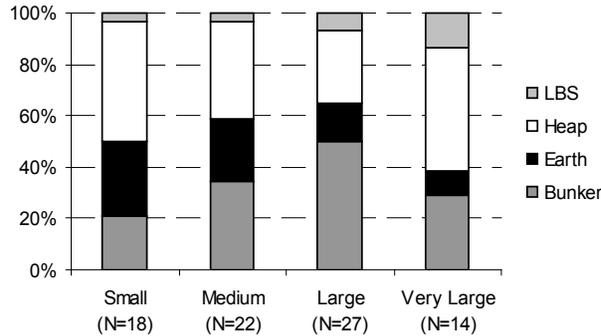


Figure 5. Silo types used by farm size categories.

did not hold for very large farms, in which more heap silos were used than bunker silos.

The average number of silos per farm was 2.1, 1.7, 2.2 and 2.0 silos for small, medium, large and very large farms, respectively. The first silo was often filled with maize from the *primera* season, while the second one contained sorghum from the *postrera* season.

Farmer criteria for silage adoption or rejection

Reasons for non-adoption and rejection. The 75 non-adopters and rejecters (37% small-, 29% medium- and 33% large-scale farmers) provided a total of 109 answers (Figure 6) as the main reasons for not using silage (any more). ‘No chopper’ was stated by 46% of small-scale farmers and 32% of medium-scale farmers. ‘No need’ integrated reasons such as ‘no feed scarcity’, ‘sufficient pasture’, ‘has irrigation’ and ‘has floodplain’. Larger farms seemed to have less need for forage conservation than smaller farms probably owing to higher availability of grazing land or other feed resources. ‘Wants to make’ was no direct reason for non-adoption but reflected the intention of farmers to adopt (potential adopters). About 32% of medium- and 11% of small-scale farmers regarded silage as expensive and beyond their financial resources (‘no money’). ‘Bad experience’ was mentioned by rejecters who were not convinced of silage making owing to previous failures, mainly with cut-and-carry grasses. ‘Lack of forage’ was mentioned by about 14% of small-scale farmers. Other reasons, mentioned 3 times

or less, are not listed in Figure 6; they included ‘lack of labour’, ‘bad cows’, ‘low milk price’, ‘lack of knowledge’, ‘lack of time’, ‘very labour-intensive’ and ‘low number of cows’.

Reasons for silage adoption. Adopters were asked what motivated them to adopt or why they started to make silage. From 52 answers, 29% referred to the lack of dry season feed and the subsequent risk of livestock production losses, which was the reason for adoption most frequently mentioned. Further motivating factors were neighbouring farmers, who had already adopted and promoted the use of silage (15%), and the project extension person, who himself was a prototype farmer and provided technical assistance, mainly in Victoria and Sulaco (12%). The positive effects on livestock production that can be observed on the adopters’ farms accounted for another 12%. Moreover, the following farmer statement is illustrative: *...in the dry season farmers suffer and they see that farmers with silage don’t suffer....*

The unavailability of farm labour in the dry season was mentioned as a driving factor by 8%. In this context, a farmer from Victoria stated: *...labour is scarce due to migration to the USA; it is easier to find young labour for one week (e.g. to prepare silage) in the rainy season than for the whole dry season... (e.g. to cut forage grass daily or to herd grazing animals).* The daily collection of grass requires up to 2 additional workers during the supplementation period.

‘Climate change’, e.g. the perceived longer and unpredictable dry season, and ‘the milk group’ (described below) accounted each for

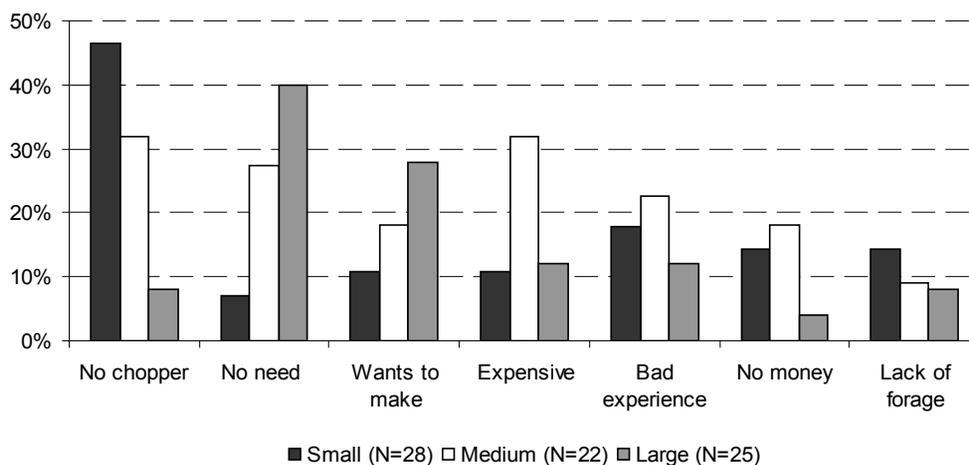


Figure 6. Main reasons for non-adoption of silage making for small-, medium- and large-scale farmers.

8%. Further reasons for adoption were 'pressure on pasture' (e.g. overgrazing), 'higher number of animals that need to be maintained' and 'the better dairy breed'.

Adopters' assessments of the effects and advantages of silage use. A total of 34 silage users were asked about the effects of silage supplementation on dry season milk production, e.g. by inquiring about milk production before and during silage supplementation. Farmers indicated that cows fed silage, mainly from maize and/or sorghum, produced more milk than those not fed silage (7.5 vs 5.0 L/cow/d; $P < 0.001$).

Farmers were asked if they noticed any further effects of silage use. Out of 64 responses, 23% mentioned the good body condition of their animals and another 3% mentioned faster calf development and growth. Good animal condition in the dry season indicates both higher production and the farmer's skills in mastering the dry season problem. 'Feed security' in times of severe drought accounted for 13% of responses. Another 10% stated advantages of silage availability such as *cows can be managed close to the farm, do not need to walk long distances and do not need to be in the hillsides where they are exposed to risk of losses due to death (e.g. steep-slope accidents) or theft*. Improvements of fertility (e.g. cows commence oestrus cycles earlier after the dry season) (9%) and health conditions (5%) including lower incidence of ticks were mentioned. Moreover, the use of silage was per-

ceived to have positive effects on pasture recuperation and production owing to reduced grazing pressure (13%). Reduced labour requirement (compared with the use of cut-and-carry grasses and sugarcane) during the silage supplementation period was mentioned by 8% of respondents. Some silage users mentioned freedom from worries about feed shortages, which was reflected by a farmer's comment as follows: *...nowadays, I'm pleased when the dry season comes, in the past I was crying....*

Farm factors influencing silage adoption

From 118 silage adopters (53%) interviewed, the share of small, medium, large and very large farms was 20, 26, 36 and 18%, respectively. The 'smallest' farmer who adopted silage had a total of 7 head of cattle, including 1 cow. The following comparison of adopters with non-adopters serves to determine factors which influence adoption.

Overall, adopters had spent more years in formal education than non-adopters, owned more cattle and more lactating cows ($P < 0.001$) and had larger farms ($P < 0.01$) (Table 3). Adopters produced higher milk yields in both rainy ($P < 0.01$) and dry ($P < 0.001$) seasons, but fed more concentrates in the dry and had more valuable cows ($P < 0.05$) than non-adopters. Ratio of cut-and-carry grass area to total farm area, and ratio of maize area for food production to total farm area

Table 3. Comparative analysis of silage adopters and non-adopters.

| Factors | Silage | N | Average | Standard deviation | Significance |
|---|--------|-----|---------|--------------------|--------------|
| Farmer's age (yr) | No | 22 | 54.5 | 12.8 | NS |
| | Yes | 49 | 49.5 | 13.7 | |
| Farmer's education (no. of years) | No | 31 | 4.9 | 5.2 | *** |
| | Yes | 52 | 10.7 | 5.6 | |
| No. of cattle | No | 103 | 52.7 | 70.4 | *** |
| | Yes | 110 | 71.5 | 76.5 | |
| No. of lactating cows | No | 77 | 10.1 | 10.7 | *** |
| | Yes | 82 | 17.8 | 14.6 | |
| Total area (ha) | No | 99 | 41.5 | 51.6 | ** |
| | Yes | 97 | 63.2 | 69.3 | |
| Maize for food/total area (%) | No | 84 | 14.1 | 15.9 | * |
| | Yes | 60 | 8.2 | 9.7 | |
| Improved/native pasture (%) | No | 102 | 40.7 | 34.5 | NS |
| | Yes | 93 | 48.7 | 35.0 | |
| Cut-and-carry grasses/total area (%) | No | 81 | 2.4 | 3.8 | ** |
| | Yes | 70 | 4.5 | 6.2 | |
| Number of cattle/total forage area (ha) | No | 98 | 1.8 | 1.3 | NS |
| | Yes | 99 | 2.3 | 1.7 | |
| Concentrate in dry season (kg/cow/d) | No | 68 | 1.3 | 1.5 | * |
| | Yes | 71 | 1.6 | 1.1 | |
| Value of cows (\$US/cow) | No | 62 | 780 | 301 | * |
| | Yes | 77 | 857 | 229 | |
| Milk yield in rainy season (L/cow/d) | No | 61 | 4.8 | 2.4 | ** |
| | Yes | 58 | 6.0 | 2.8 | |
| Milk yield in dry season (L/cow/d) | No | 78 | 3.4 | 2.6 | *** |
| | Yes | 77 | 5.2 | 2.8 | |

were higher on farms of adopters. Adoption was independent of farmer age, stocking rate and ratio of improved pasture to native pasture. However, when very large farmers were excluded from the analysis (because they had relatively larger areas of improved pasture), the ratio of improved pasture to native pasture of silage adopters was higher ($P < 0.01$) than that of non-silage users (51 vs 36%).

Non-silage farmers milked 9.2 cows in the dry season and 10.2 in the rainy season, compared with 19.0 cows on silage farms in the dry season

and 17.6 cows in the rainy season. Although relatively more silage users had off-farm income than non-silage users (45 and 31%, respectively), the difference was not significant.

Silage adopters were more specialised in live-stock husbandry than non-adopters, which was indicated by a lower share of mixed farming systems (17.4 and 23.2%, respectively) and a proportionally smaller area ($P < 0.05$) dedicated to maize production in relation to total farm size (14.1 and 8.2%, respectively). Moreover, farms with silage have a higher intensification level shown by a

higher share of dairy breeds and of cultivated forage area. About 80% of silage users have cut-and-carry grasses compared with about 62% of non-silage users (data not presented). Milk production on farms using silage was 1.8 L/cow/d (dry season, 53%) and 1.2 L/cow/d (rainy season, 25%) higher than on farms where no silage was fed. Dry season milk production was 87% and 71% of the milk produced in the rainy season for silage users and non-silage users, respectively.

Effect of promotion strategies and intensities on silage adoption

Within 3 years (2003/04 – 2006/07), adoption of silage technology increased from 18% to 38% of participating farmers (Table 4). Depending on the research location, the strategy ‘promotion of innovation’ (PI) resulted in total adoption of 0–29% with an average of 19%. Adoption increases ranged from –5% to 24% between 2003/2004 and 2006/07, with an average increase of about 9%. In contrast, ‘promotion of adoption’ (PA) resulted in total adoption of 13–79%, with an average of 57%. Adoption increases ranged from –40% to 57% between 2003/2004 and 2006/07, with an average increase of about 31%. The difference in total adoption between the strategies was signifi-

cant ($P < 0.05$). Moreover, more farmers intended to adopt (‘potential adopters’) with PA (13%) than with PI (5%), whereas rejecters accounted for 7% and 6%, respectively. With respect to extension intensity, adoption increases were 12.5, 10.4 and 32.7% for low, medium and high extension intensity, respectively.

Case study: Adoption and diffusion of silage technology in the Yoro area

This case study showed silage adoption and diffusion in the area of Yoro, where silage was promoted under strategy PA and high intensity. Promotion of silage making was initiated in 2002 and 2003 by CIAT/DICTA through field days and workshops involving farmers from Victoria, Sulaco, Yorito and Yoro. The total number of adopters in the area increased from 11 farmers in 2002/03 to 102 farmers in 2006/07 (26 from Yoro, 15 from Yorito, 28 from Sulaco and 33 from Victoria) (Figure 7). The dashed lines in the figure represent the minimum diffusion course based on the intentions of contacted farmers to produce silage for the dry season 2007/08. In 2007/08, the proportions of all livestock keepers in the 4 locations making silage were: 23% in Yoro, 36% in Yorito, 41% in Sulaco and 37% in Victoria.

Table 4. Effect of farmer training on silage adoption of participants.

| Location | Extension strategy | Extension intensity | No. of farmers participating in training | No. of adopters in 2003/04 | No. of adopters in 2006/07 of participants | % silage adoption ¹ | % silage adoption increase ² |
|--------------------------|--------------------|---------------------|--|----------------------------|--|--------------------------------|---|
| San Pedro de Catacamas | PI | Low | 18 | 0 | 2 | 11 | 11 |
| San Francisco de Becerra | PI | Low | 21 | 1 | 6 | 29 | 24 |
| San Francisco de la Paz | PI | Low | 17 | 0 | 0 | 0 | 0 |
| Jesús de Otoro | PI | Medium | 8 | 0 | 1 | 13 | 13 |
| Las Vegas | PI | Medium | 14 | 0 | 3 | 21 | 21 |
| Alauca | PI | Medium | 10 | 0 | 2 | 20 | 20 |
| Jamastrán-2 (NITs) | PI | Medium | 40 | 12 | 10 | 25 | -5 |
| Jamastrán-1 | PA | Medium | 24 | 5 | 11 | 46 | 25 |
| Victoria | PA | High | 29 | 7 | 20 | 69 | 45 |
| Sulaco | PA | High | 19 | 7 | 15 | 79 | 42 |
| Yorito | PA | High | 23 | 4 | 12 | 52 | 35 |
| Yoro | PA | High | 21 | 3 | 15 | 71 | 57 |
| Candelaria | PA | High | 15 | 8 | 2 | 13 | -40 |

¹Total adoption of farmers who participated in training sessions and/or were supported by a project technician.

²% adoption increase between 2003/04 and 2006/07 = (no. of silage adopters 06/07 – no. of silage users until 2004 who participated) / (no. of participating farmers).

The proportion of small-scale farmers making silage increased from 0% in 2003 to 16% in 2007, while percentage adoption in medium- and large-scale farmers decreased from 31% to 28% and from 54% to 41%, respectively. Ninety percent of adopters used bunker silos in 2003 compared with only 50% in 2006. Sorghum ensiled in heap and earth silos became more popular and was increasingly being adopted by silage novices.

Influence of the milk market and organised farmer groups on silage adoption. Silage adoption by farmers affiliated with CRELs (Spanish acronym for Milk Collection and Cooling Centres) or, as in the case of Sulaco, with a farmer association (AGASUL, Asociación de Ganaderos y Agricultores de Sulaco), was higher than the overall adoption for all farmers (Figure 8). In 2007, about 80% of the 21 group members had a silo

in Sulaco, more than 60% in Victoria and about 40% in Yorito and Yoro. Farmers who pioneered silage making were almost all CREL group members, whereas many non-CREL farmers adopted silage making only recently. As corroborated by 3 independent key informants pertaining to a CREL in Jamastrán (El Paraíso), about 80% of group members fed silage, whereas total adoption in the region was estimated to be less than 20%.

Discussion

This study has highlighted some of the key factors, including technological, socio-economic and extension aspects, which influenced silage adoption and diffusion in Honduras. From an analysis of these issues, recommendations for silage extension are proposed.

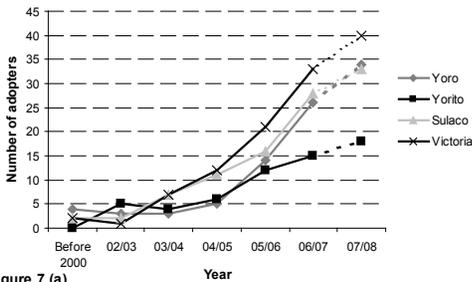


Figure 7 (a)

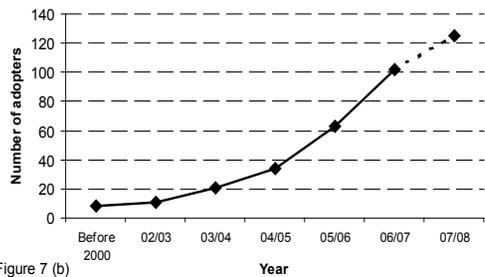


Figure 7 (b)

Figure 7. Progressive adoption of silage technology over time in 4 locations of the Yoro area: (a) in individual locations; (b) total of locations.

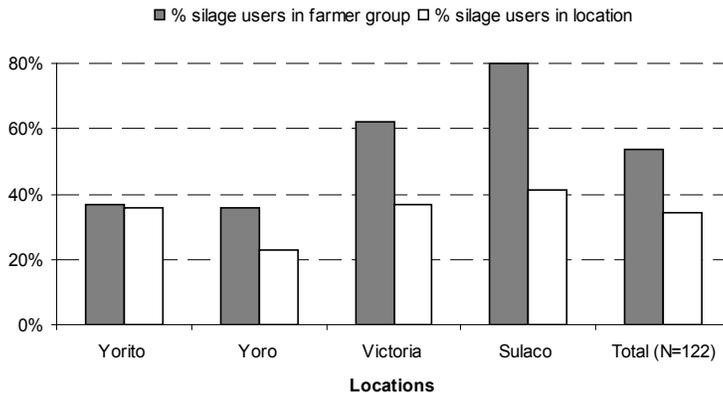


Figure 8. Silage use in farmer groups compared with local adoption.

Technological considerations

Research has consistently found that how farmers perceive an innovation, *e.g.* its compatibility with their system, its complexity, observability, trialability and relative advantage, affects how likely potential adopters are to move from awareness to adoption (Bradford and Florin 2003; Rogers 2003). Our study showed that Honduran farmers perceived making silage from maize and sorghum as simple technologies producing forage of high quality and palatability capable of supporting livestock production, with low spoilage losses (usually below 5%).

However, farmers perceived that making of tropical grass silage was more complex in terms of the ensiling process, losses were greater and livestock responses were lower than with sorghum or maize silage. Reasons were attributed mainly to the lower concentrations of water-soluble carbohydrates (WSC) in tropical grasses and their lower DM content at harvest, compared with maize and sorghum (Catchpoole and Henzell 1971). Farmer experience was that, in contrast to maize and sorghum, tropical grasses required adequate wilting and addition of additives such as molasses to ensure good fermentation. The preparation of high quality grass silage therefore required more profound knowledge and more intensive training not only of farmers but also of extension personnel.

While all types of silos were adopted by some farmers in all farm size categories, the exclusive use of bunker silos in Yorito suggested that a champion(s) of this silo type, who was most influential, was very active in this area. It was especially surprising as this was an expensive storage method in a situation where the aim was to keep feed costs as low as possible. This situation highlighted the danger in having influential people promoting methodologies that were not necessarily optimal. Potentials and constraints of LBS for smallholders were discussed elsewhere (Reiber *et al.* 2009).

Reasons for silage adoption or rejection

As indicated by Shelton *et al.* (2005), adoption of new technology is influenced by a number of factors: the technology must meet the needs of farmers; building relevant partnerships enhances adoption; an understanding of the socio-economic

context and skills of farmers and their farming systems is essential; participatory involvement of the rural communities enhances adoption; and the long-term involvement of champions ensures the process does not stall and problems are resolved. In our study, the farmers had a clearly identified problem/need, *e.g.* a shortage of good quality feed during the dry season. Silage had the potential to satisfy this need by providing a high quality feed at this time, as indicated above. As indicated by Alvarado Irias (2005), in the case of small- and medium-sized farms, the economic situation was the most limiting production factor for the adoption of technologies that required initial investments. Our study indicated that a farmer's economic situation, which was partly reflected by the number of animals and farm size, influenced adoption, with adopters running more cattle (including more lactating cows) and having larger farms than non-adopters. The lack of chopping equipment requiring a substantial investment was identified as a major limiting factor for poor smallholders. As suggested by Wilkins (2005), the cooperative purchase, administration and use of choppers would provide a mechanism to overcome this impasse.

Adopters had more valuable cows than non-adopters and produced more milk during both rainy and dry seasons. Since the value of a cow was determined by her milk production, this was a function of both her genetic potential and her nutritional plane. The content of European dairy breed genes in her genetic make-up affected her genetic potential for milk production. An adequate feed base, particularly during the dry season, was prerequisite for the farmer to benefit from crossbred cows of higher milk production potential (Chilliard 1991; Vélez *et al.* 2002). It was possible that, in our study, access to genetically more productive animals was an effective incentive to improve feeding and management. Farmers stated that milk production should be at least 7 L/cow/d if silage making was to be profitable.

The importance of level of education in adoption of this technology was consistent with the findings of other workers on adoption of forages, *e.g.* Lapar and Ehui (2005), although Gebremedhin *et al.* (2003) found that, while formal education/literacy was important in accessing information, it was not positively associated with level of adoption of technology. Our findings suggested that better educated farmers may

be more capable of recognising the benefits of adopting the technology. In this context, education should not be interpreted only as formal education but should encompass the whole range of training activities that provide information and knowledge dissemination.

Organised farmer groups or organisations have been shown to be the key to success for small scale dairying. Formation of farmer groups, cooperatives and community-based organisations is necessary to alleviate some of the common forage, dairy production and marketing problems hindering development, and to press governments to improve infrastructure. Moreover, groups are better able to access financial aid and then invest in appropriate resources, *e.g.* machinery, milk tanks and milk processing facilities, which improves the market position of smallholders (Orodho 2005; Bennett *et al.* 2006). The increased adoption rates by farmers affiliated with farmer organisations, *e.g.* CRELs, in our study supported this reasoning.

Access to markets and adequate prices for milk produced are vital for farm viability. CRELs represent a breakthrough opportunity to strengthen small- and medium-size dairy operations in Honduras (Toro Alfaro 2004). Alvarado Irías (2005) indicated that producers who sell their milk to the local market are less able to pay their production costs than producers who operate in an industrial market (that is, belong to CRELs); this is largely due to the lower price paid for the artisan-produced milk, and not because of incorrect or poor financial management. However, physical infrastructure (*e.g.* poor road access) and the lack of means for milk preservation (*e.g.* refrigeration) or processing limit market access in remote areas (Bennett *et al.* 2006).

The major reasons for non-adoption of silage technology in our study were in line with preceding comments. Forty percent of large farmers indicated they had no need for silage, while lack of a chopper and high cost of silage were identified as factors preventing adoption by medium and small farmers. The latter two reasons were aligned with a lack of financial resources or a perception that returns would not meet inputs. In Nicaragua, the main reasons for low adoption of forage conservation by smallholders were lack of technical assistance, the unavailability of suitable forage species and the need for investment (Belli 2003). Mannetje (2000) listed the following reasons for non-adoption of silage in Pakistan, India

and Thailand: lack of know-how, lack of finance, lack of farm planning, lack of available forage of good quality and low genetic production potential of animals. Costs, time and effort for silage making were not matched by adequate returns. He concluded that technology of any kind would be adopted only if it could be part of production systems that generated regular income and adequate return on investment.

Extension strategies and intensities

The study showed that the introduction, experimentation, evaluation and promotion of technologies, represented by 'promotion of innovation' (PI), showed adoption rates of up to 24% within 3 years. Further experiences from Gualaco (Olancho), where forage conservation was introduced by CIAT and GTZ in 2003, and from San Lucas (El Paraíso), where an FAO project (PESA) promoted forage conservation in 2004/2005, confirmed that short-term (less than 3 years) promotion and extension initiatives can lead to some adoption but that such a time horizon may not be sufficient to stimulate an independent farmer-to-farmer technology diffusion process.

Promotion over a longer time period represented by the extension strategy 'promotion of adoption' (PA) did not lead to higher adoption under adverse conditions (*e.g.* inadequate ensiling methods, financial constraints) such as in Candelaria. However, this strategy led to adoption rates of up to 57% within 3 years under favourable conditions (presence of key innovators, motivated farmer groups and a favourable milk market) such as in the Yoro case. The reason for higher adoption with PA compared with PI does not necessarily indicate differences in quality or effectiveness of the different strategies but probably results from the fact that promotional activities with PA were built on local experience and knowledge that had developed through earlier promotional activities; thus, PA started at an advanced stage of the technology diffusion process, after which adoption rates are usually higher.

The Yoro case study showed a silage diffusion process with an S-shaped rate of adoption (Figure 7b) similar to the adoption curve described by Rogers (2003), who argued that the speed of the diffusion process of a successful innovation was determined mainly by the extent of the interac-

tion between people who have already adopted and those who have not yet adopted. Furthermore, the speed of diffusion is dependent on the innovators at the same time being key communicators and influentials (Albrecht 1969). Rapid diffusion with high adoption rates (like in Jamastrán, Yoro) occurred where: (a) communication and interaction between adopters and non-adopters were fostered, (b) farmer groups existed and (c) leader farmers emerged as part of the promotion process (farmer-to-farmer).

Challenges for silage extension

As with promotion of any technology, each situation needs to be analysed to identify the most limiting and supporting factors affecting whether the target groups might change their behaviour (Albrecht 1969; Gabersek 1990) and then to determine interventions with suitable technologies (dry season forage, in the case of this study) either to alleviate bottlenecks and restrictions or to increase productivity. Farmers' problems, objectives and priorities are the basis for the selection of suitable technologies to be introduced, tested and promoted with farmers.

The challenge is to optimise extension efficiency by identifying the best allocation of limited financial and labour resources to achieve maximum adoption within a certain time frame. Therefore, it is important to assess the extension intensity required to stimulate a technology diffusion process. Witt *et al.* (2008) showed that training intensity, defined as the share of trained farmers within a village, was decisive for diffusion of information on Integrated Pest Management. They suggested the optimal training intensity to be at about 24–28% to attain effective dissemination of information and to generate positive stimuli for adoption and learning among farmers who were not reached by extension. For the diffusion of innovations, Rogers (2003) concluded that, once 10–20% of the targeted farmers have adopted, the diffusion process often continues independently and without further interference from outside. In this context, Dalsgaard *et al.* (2005) stated that successful and sustained introduction of alternative, farmer needs-based approaches and methods, within public extension systems, required more time and effort than was recognised and allocated for in most development projects and programmes. Thereby, success was

the result not only of adoption and technological performance but also of how technology linked to knowledge sharing, networks and capacities. Innovation processes involved continuous on-site cycles of learning and change, and required the integration of local partners (Kiers *et al.* 2008; Lilja and Dixon 2008).

Conclusions

Smallholder crop livestock farmers were motivated to make silage in environments where (a) seasonal lack of feed particularly in drought-prone areas (that is, with more than 4.5 dry months) caused great production losses (*e.g.* reduced milk production and death of cattle) and (b) organised and motivated farmers with market-oriented dairy production existed or were emerging.

Increased usage of silage-making technology using improved forages and feeds to overcome the dry season feed deficits in the dry tropics seemed possible by application of appropriate technology transfer strategies. Farmer motivation and participatory technology experimentation, evaluation and development were particularly important in areas where silage was less known. Once there are positive examples, adapted and efficient silage technologies should be scaled-out through demonstrations and exchange of experiences ('promotion of adoption' and/or farmer-to-farmer approach). However, other constraints such as lack of finances to purchase choppers need to be addressed to ensure maximum adoption. The purchase and management of co-operatively owned equipment should be investigated to remove this barrier to adoption by poorer farmers.

R&D initiatives must foster communication and cooperation among farmers and other stakeholders and develop improved marketing conditions for livestock products in order to foster adoption of technology by smallholders to increase production. The use of an integrated, flexible, situation-specific and participatory extension strategy involving different dry season forage technologies that can be adapted to the demands and needs of farmers is required to support a sustainable forage and livestock development process.

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