SHRUBS AND TREE FODDERS FOR FARM ANIMALS

PROCEEDINGS OF A WORKSHOP IN DENPASAR, INDONESIA, 24 – 29 JULY 1989

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Shrubs and tree fodders for farm animals

Proceedings of a workshop in Denpasar, Indonesia, 24–29 July 1989

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Abstract

This publication presents the results of an international meeting held in Denpasar, Bali, Indonesia, 24–29 July 1989, that focused on the use of shrubs and tree fodders by farm animals. Through 26 papers, the workshop addressed feed-resource availability, use by ruminants and nonruminants, processing methodology, economics, and development issues. These aspects and the current knowledge on shrubs and tree fodders were further highlighted by country case studies detailing prevailing situations and policy matters. A special session was held to discuss the successful development and results achieved in the three-strata forage system in Indonesia. The workshop concluded with important working group discussions on the priorities for further research and development, and on the potential for the wider use of shrubs and tree fodders in the developing world.

Résumé

Cette publication présente les résultats d'une rencontre internationale tenue à Denpasar, Bali, Indonésie, du 24 au 29 juillet 1989 et qui a porté sur l'utilisation des arbustes et fourrages végétaux par les animaux d'élevage. Les 26 communications qui y ont été présentées traitaient de la disponibilité des ressources alimentaires pour les animaux, de leur utilisation par les ruminants et les non-ruminants, des méthodes de transformation, des aspects économiques et des questions du développement. Ces sujets et les connaissances actuelles sur les arbustes et les fourrages végétaux ont ensuite été étudiés plus à fond dans le cadre d'études de cas de divers pays exposant les circonstances particulières de chacun et les questions liées aux politiques. Une séance spéciale a porté sur la mise en place et les résultats des systèmes de production de fourrages végétaux en trois strates en Indonésie. L'atelier s'est terminé par d'importantes discussions des groupes de travail sur les priorités de recherche et de développement pour l'avenir et sur les possibilités d'utilisation élargie des arbustes et des fourrages végétaux dans les pays en développement.

Resumen

Esta publicación presenta los resultados de una reunión internacional celebrada en Denpasar, Bali, Indonesia, del 24 al 29 de julio de 1989, y la cual centró su atención en la utilización de forrajes elaborados a partir de arbustos y árboles para alimentar a animales de granjas. En 26 trabajos presentados al seminario, los participantes abordaron temas tales como la disponibilidad de recursos alimentarios y la utilización de los mismos por rumiantes y no rumiantes, metodologías de procesamiento y cuestiones de economía y desarrollo. Estos aspectos y el conocimiento que se tiene actualmente sobre los forrajes de arbustos y árboles se vieron subrayados aún más por estudios de casos por países en los que se detallaron situaciones existentes y cuestiones de políticas. Se celebró una sesión especial para discutir el desarrollo y resultados exitosos alcanzados en Indonesia con el sistema de forraje de tres niveles. El taller concluyó con importantes discusiones de los grupos de trabajo sobre las prioridades existentes en el campo de la investigación y el desarrollo y sobre el potencial que encierra la amplia utilización de arbustos y árboles en el mundo en desarrollo.

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Research protocols appropriate to the development of methodology for the three-strata forage system

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Abstract *— Three-strata forage system (TSFS) research protocols consist of objectives, design, site and farmer selections, forage system, stocking rate, soil status, climatic condition, and statistical analysis. Because the TSFS approach is integrated, the methodology is based on assessing forage quantity and quality, cattle feeds and feeding, soil erosion, the interrelation among grasses, ground legumes, shrub legumes, and fodder trees, and the interrelation among climatic factors, topography, and forage yield. These assessments also allow for the measurement of food, feeds, firewood, carrying capacity, and environment conservation. To assess the full benefit of fodder trees as feed sources, such studies should be carried out for at least 6 years.*

Résumé *— Les protocoles de recherche sur le régime à trois espèces fourragères (RTEF) consistent à déterminer les objectifs, le plan et le site de la recherche, à choisir les paysans, à établir le système de fourrage, le taux de charge, l'état des sols, les conditions climatiques et à faire des analyses statistiques. Parce que le RTEF est un régime intégré, la méthodologie se fonde sur l'évaluation de la quantité et de la qualité des fourrages, des aliments et de l'alimentation du bétail, de l'érosion des sols et de l'interrelation entre les graminées, les légumineuses, les légumineuses arbustives et les arbres fourragers comme l'interrelation entre les facteurs climatiques, la topographie et le rendement des fourrages. Cette évaluation permet aussi de mesurer les cultures vivrières, les plantes fourragères, le bois de chauffe, la capacité de charge et la conservation de l'environnement. Pour bien évaluer pleinement les avantages des arbres fourragers comme source de fourrage de telles études doivent s'étendre sur au moins six années.*

Resumen *— Los protocolos de investigación del sistema de forraje en tres capas (TSFS) consisten en objetivos, proyecto, selecciones de lugar y granjero, sistema de forraje, densidad de pastoreo, estado del suelo, condición climática y análisis estadístico. Como el TSFS es una técnica integrada, la metodología se basa en la evaluación de calidad y cantidad de piensos y alimentación del ganado vacuno, erosión del suelo, interrelación entre gramíneas, legumbres, arbustos leguminosos y árboles forrajeros, así como entre los factores climáticos, la topografía y el rendimiento del forraje. Estas evaluaciones también permiten la medición de productos alimenticios, forraje, leña, capacidad de carga y protección del medio ambiente. Para efectuar la evaluación de todos los beneficios que reportan los árboles forrajeros como fuentes alimenticias, deben llevarse a cabo dichos estudios por lo menos durante seis años.*

Introduction

In the traditional farming system in dryland areas in Bali, food crop production is the main activity; livestock production is a sideline. The concept of the three-strata forage system (TSFS) has been described by Nitis et al. (this volume). In TSFS, forage, food crop, and cattle complement each other. The research methodology was aimed at answering the broad and specific objectives of TSFS. This paper describes the research protocols, methodology, and productivity of TSFS.

Research protocols

Objectives

The overall objective of TSFS is to increase farmers' incomes through improved land management involving crop–animal systems. The specific objective is to define a three-strata production model for food and feed for the semi-arid rainfall areas of Bali. This is done by

- evaluating growth and yield of grasses, legumes, shrubs, trees, and crop components;
- measuring the nutritive value of the feed sources produced in the system;
- measuring the performance (growth, feed intake, and carcass quality) of Bali cattle;
- evaluating carrying capacity; and
- comparing the economic and ecological advantages of TSFS to the existing traditional system (non-three-strata forage system, NTFS).

Design

The factorial design is a completely randomized arrangement consisting of two forage systems (strata and nonstrata), two stocking rates (2 and 4 cattle/ha), and 11 and 10 replications for the low and high stocking rates, respectively.

Site selection

The site is a dryland farming area in the semi-arid climatic zone (4 months wet and 8 months dry), with emphasis on cattle development. The site is also outside the area designated for industrial and tourist development. The topography is undulating, with 30% flat area and 70% sloping area.

Farmer selection and participation

The farmers selected own more than 0.25 ha of land, till their own land, raise cattle, own water catchments, are members of farmers group, are willing to surrender 0.25 ha of land to forage production, and participate actively in the project. Of the 26 farmers selected, 12 were for TSFS and 14 were for NTFS. Each farmer looks after at least one plot and, at the most, four plots.

Forage system

Plot allocation

The 20 ha of land was divided into 8-, 8-, and 4-ha areas for TSFS, NTFS, and tether grazing, respectively. Another 0.25 ha was allocated for cattle weighing, the forage nursery, and demonstration purposes.

The TSFS and NTFS area was divided equally into 50 × 50 m (0.25 ha) plots (each plot was not necessarily square — it is difficult to get a uniform layout). Therefore, there were 64 plots of 0.25 ha each in the 16-ha area. Because of the undulating topography, 22 plots were sloping (S), 22 were flat (F), and 20 combined flat and sloping land (FS).

Forage and cash crop allocation

The allocation of cash crops in the core area, the first stratum in the peripheral areas, and the second and third strata in the circumference area of the TSFS have been described by Nitis et al. (this volume). The 0.25-ha NTFS plot was not divided into core, peripheral, and circumference areas. Instead, the entire area was planted with cash crop. Four tree fodders were planted at the corners of the NTFS as a boundary.

Planting and establishment

After ploughing and harrowing the land, cuttings of ficus (*Ficus poacellie*), lannea (*Lannea corromandilica*), and gliricidia (*Gliricidia sepium*) were planted at the onset of the wet season (end of October). Hibiscus (*Hibiscus tilliaceus*), however, were planted in the wet season; planting during the dry season would cause the stems to dry and peel. Buffel grass (*Cenchrus ciliaris* cv. Gayndah), green panic (*Panicum maximum* var. *trichoglume*), legume centro (*Centrosema pubescens*), common stylo (*Stylosanthes guianensis* cv. Graham), Caribbean stylo (*Stylosanthes hamata* cv. Verano), and leucaena (*Leucaena leucocephala*) are planted as seeds after the appropriate scarification during the wet season (December). Resowing and replanting are carried out 1 or 2 months after planting. The plants are then allowed to establish for 12 months. The corn, soybean, and cassava are planted simultaneously in November every year. Corn is harvested in February, soybean in March, and cassava in July, as is commonly done by farmers.

Stocking rate arrangement

Because the land is divided into 0.25-ha units instead of 1.0-ha units, the stoking rate was arranged according to the 0.25-ha plot size. That is, the 2 cattle/ha stocking rate is equivalent to one head of cattle for two plots (0.5 ha). The 4 cattle/ha stocking rate is equivalent to one cow per 0.25-ha plot. When two plots are allocated for one cow, the plots are contiguous.

Of the 50 cattle bought in the local market, 21 were for TSFS (10 for the higher stocking rate, 11 for the lower stocking rate), 21 were for NTFS, and 8 were raised traditionally.

Soil status

The limestone-based soil is a red brown Mediterranean type (Winaya et al. 1980). The F, S, and FS plots contained 2.78, 2.97, and 2.21% organic matter, and 0.045, 0.299, and 0.159% total nitrogen, respectively.

Climatic condition

Rainfall was recorded daily at the centre of the project site. The temperature and relative humidity was recorded by a thermohydrograph, also at the centre of the project site.

Statistical analysis

The parametric data was analyzed using the analysis of variance (Steel and Torrie 1960); nonparametric data was analyzed with the χ^2 test (Gomez and Gomez 1976). Where appropriate, data were subjected to regression analysis (Sokal and Rohlf 1969).

Development of TSFS methodology

Forage

For the grass and ground legume used as samples, 0.5 × 0.5 m quadrats were used. Marked with iron rods, each quadrat is located 1 m from the shrubs and the trees and is on the border of the adjacent grasses, legumes, and cash crops (see Fig. 1 in Nitis et al., this volume, p. 94). For shrub legumes, one plant in the middle of the row and two plants 1 m from the adjacent tree are tagged with a zinc plate. For fodder trees, those opposite the quadrat and those 1 m from the selected shrub legumes are used as samples. The quadrat and the tag in F, S, and FS plots were arranged so that each treatment was replicated 9 times.

Grasses and ground legumes were cut at 15 cm, leucaena at 1 m, and gliricidia at 2 m heights. The fodder trees were lopped at average branch level. Cutting and lopping were done twice a year: at the end of the wet season (mid-March) and at the end of the dry season (mid-November). For the grasses and ground legumes, the density, weed infestation, height, and fresh weight were recorded. For the shrubs and trees, height, length of lopping, number of branches, number of leaves, and fresh weights of the branch and leaves were recorded. A 100- to 500-g subsample from each observation was taken for dry weight determination. Samples were dried in a forced-draught oven at 70°C to a constant weight.

Forage yield

The 4th-year harvest (Nitis et al. 1987) gave the following results:

- Yield of the first stratum was higher than that of the third stratum; yield of the third stratum was higher than that of the second stratum.

- Yield during the wet season (4 months) was higher than that of the dry season (8 months).
- Yield of the sloping (S) plots was higher than that of the flat (F) plots.
- Yield of graham stylo decreased after 3 years of continuous cuttings.
- The lower yield of leucaena was due to *Heteropshylla*. Guzadrin and azodrin spraying was ineffective in controlling this attack.
- Hibiscus did not grow well on the sloping plot.

Association among grasses, legumes, shrubs, and trees

Apart from the forage shoot yield sample, nodules in the soil of the flat plots were taken using an auger at 0–20 cm depth at 25, 50, and 100 cm from the respective shrub legumes at the end of the wet season. The soil was flushed with water and passed progressively through 50- and 10-mm sieves to separate the nodules, roots, and soil. Nodule activity was then evaluated (Skerman 1977).

The results of the 4th-year harvest (Nitis et al. 1987) and the nodulation showed the following:

- There was an interrelationship between the plants in the first, second, and third strata and this interrelationship changed with the season.
- Gliricidia and its association with grasses produced heavier and more nodules. However, the nodules were smaller than those found on gliricidia in association with ground legumes. A similar trend was observed for leucaena.
- At the end of the wet season, nodule activity of shrub legumes varied from 40 to 60%. This activity was unaffected by grass and ground legume species.
- Nodulation on gliricidia decreased markedly away from the main root; on leucaena, however, nodulation is evenly distributed.

Microclimate and forage growth

Where cenchrus was associated with gliricidia or leucaena, quadrat sampling was done at 0.5, 1.0, 1.5, 2.0, and 2.5 m from the middle row of the fenceline. Beside the quadrat, soil moisture, soil temperature, and light intensity under the cenchrus canopy were determined. Similar tests were also carried out for verano stylo.

Soil moisture, soil temperature, and light intensity were recorded in the morning (0700–0900), around noon (1200–1300), and in the afternoon (1500–1600); each measurement was repeated 9 times. Density, tiller number, and the area covered by the cenchrus and verano stylo were recorded at the same time.

The results showed the following (Nitis et al. 1986):

- Soil moisture and soil temperature under cenchrus and verano stylo canopies are unaffected by association with gliricidia and leucaena.
- Light intensity under the gliricidia canopy in association with cenchrus was lower than that under leucaena. A similar trend was observed for verano stylo.

- The growth (plant density, tiller number, and cover) of cenchrus and verano stylo was affected more by the shading of shrub legumes than by soil moisture or soil temperature.

Rainfall and forage yield

The TSFS experiment was carried out in a dryland farming area with an average annual rainfall of 1 000 mm, with 116 rainy days distributed through the 8-month dry season and the 4-month wet season. The 3 years of data on rainfall and forage yield showed the following:

- The yield of grasses was higher than that of legumes.
- The coefficient of determination for cenchrus was highest; that of panicum was lowest. The effect of the dependent variables varied among forage species.
- The higher yield of cenchrus was due to its greater responsiveness to precipitation; there was enough moisture to sustain a longer growing period.
- The lower yield of legumes was due to its greater responsiveness to the first rain, which is usually insufficient for good regrowth.

Forage conservation

After digging and cutting limestone to make bricks, the holes are left unattended. These holes, with a bit of adjustment to the wall and the dimensions, can be used as a trench silo.

Silage was made with leaves of gliricidia, leucaena, verano stylo, and lannea. Such leaves are not good for hay because the leaf blades shatter during drying. Silage was made in February and used in May 1986 (Nitis et al. 1986). The results showed the following:

- Based on physical characteristics (odour, flavour, colour, and consistency), the silage is good.
- Based on chemical characteristics, gliricidia silage is inferior.
- Gliricidia silage was low in dry matter and crude protein.

Even though the silage was rated good, farmers were reluctant to make it because of the time spent cutting the forage and filling the holes. An alternative method is under consideration.

Cash crops

In the TSFS plot, four samples were taken. Each sample was in the border of either the grasses or the legumes (see Fig. 1, Nitis et al., this volume, p. 94). Another sample was taken in the middle of the plot. For the NTFS plot, four peripheral samples were taken 5 m from the border of the plot and one sample was taken in the middle of the plot. Samples were taken on the flat (F), sloping (S), and FS plots, with nine replications each.

Samples were collected just before cash crop harvest. For soybean, each sample was taken within a 0.5 × 0.5 m quadrat; for corn and cassava, each sample was taken within a 1 × 1 m quadrat. Absolute samples (i.e., yield of each plot) were taken for comparison. Fresh weights of corn and soybean grains, cassava tubers, corn stovers (including the bean peel), and cassava tops (stem and some leaves) were also recorded.

To study the effect of grasses and ground legumes on the cash crop, samples were taken 0.1 and 2 m from the forage border on the top, bottom, and either side of each sloping plot. Four similar sloping plots were selected for replication.

The 4th-year harvest (Nitis et al. 1987) gave the following results:

- In TSFS, yields of the grains, tubers, and straws from S plots were lower than those from F and FS plots. A similar trend was observed for NTFS.
- Corn was affected the most and cassava was affected the least by sloping gradients.
- The cash crop grown in association with panicum produced more grains, tubers, and straws than the cash crop in association with cenchrus.
- The cash crop grown in association with 'Graham' stylo produced more grains, tubers, and straws than the cash crop in association with either verano stylo or centrosema.
- Ground legumes had a greater favorable effect on cash crop than did grasses.
- Corn and soybean yields were unaffected, but cassava yields increased with increasing distance from the forage border (Nitis et al. 1988). The highest cassava yields were 1 m from the cenchrus border.

Chemical composition and nutritive value

The interrelationship between grasses, legumes, shrubs, trees, the three topographies (F, S, and FS), and the nine replications gave a total of 2 079 samples per harvest. For chemical analysis, the number of replications was reduced to three by pooling samples. Dry matter was determined by drying the ground sample at 105°C to a constant weight. The crude protein, gross energy, acid detergent fibre, and neutral detergent fibre contents were determined according to Wolfenden (1982).

The following results (Nitis et al. 1986; Nitis et al. 1987; Nitis et al. 1988) were obtained:

- Topography had no effect on the chemical composition of grasses, ground legumes, shrubs, and trees.
- Plants in the first and second strata had no effect on the chemical composition of plants in the third stratum.
- Plants in the second and third strata had no effect on the chemical composition of plants in the first stratum.
- Plants in the first and third strata had no effect on the chemical composition of plants in the second stratum.

- The chemical composition of soybean straw and cassava leaves were not affected by the association of the plants with grasses and legumes.

In vitro dry matter digestibility

Twelve 2-kg samples of forage, offered to the cattle, were collected every 28 days (Nitis et al. 1986). The 12 samples consisted of 6 samples from TSFS and 6 from NTFS cattle. Each group of 6 samples consisted of 3 samples from the high stocking rate and 3 from the low stocking rate. The three samples from the low and high stocking rates were associated with the three topographical conditions (F, S, and FS).

Three replicate samples of cenchrus, panicum, centrosema, and verano stylo under low and high stocking rates and the three topographical conditions were taken at the end of the wet season (March 1988) (Nitis et al. 1988). The technique used is that of Jones and Hayword (1975) adapted by Goto and Minson (1977) using 2.5% cellulase (Onozuka SS p-1500). The following results were obtained:

- Season had no effect on the dry matter digestibility (DMD) of the cattle diet.
- DMD of TSFS cattle diet was 5% higher than that of NTFS cattle diet.
- DMD of the cattle diet from F and FS plots was 12–14% higher than that from the S plot.
- The DMDs of grasses and two legumes at the high stocking rate were slightly higher than those at the low rate. DMDs of the two grasses and the two legumes in the F plots was slightly higher than those in the S plots. These differences were not significant.

Allelophatic factors

The growth of cenchrus with gliricidia was not as good as its growth under leucaena. The possibility of the presence of an allelophatic factor was examined. Extracts of fresh gliricidia leaves and roots and the soil under gliricidia were used in solution to water cenchrus plants (in plastic pots in a greenhouse). The experiments were replicated six times. The cenchrus watered with extract of gliricidia soil produced fewer leaves and tillerers and lower shoot yield than those watered with the other extract solutions (Nitis et al. 1987).

Deleterious substances

In a mixed diet, gliricidia consumption by cattle was 40–60%; when gliricidia was fed alone, consumption was 76%. The possible presence of deleterious substances affecting palatability and intake was studied by taking 250-g leaf samples from the top and bottom branches of gliricidia grown in association with cenchrus, panicum, centrosema, or verano stylo on flat and sloping plots. Samples were taken at the end of the wet season (March 1987). Specific compounds were determined spectrophotometrically by the HCl–vanillin method (T. Horigome, personal communication).

The following results were obtained (Nitis et al. 1988):

- Flavonol content is higher in younger leaves than in older leaves.
- Gliricidia leaves from the S plot contained more flavonol than those from the F plot.
- The highest flavonol content was found in the leaf grown in association with centrosema on the S plot; the lowest content was found in the gliricidia grown in association with panicum on the F plot.
- Catechen and total phenol contents were unaffected by these parameters.

Cattle performance

Live weight gain and feed conversion

The average initial live weight of castrated Bali steers was 122 kg. Each steer was weighed every 28 days. For TSFS, forage are cut from the allocated plot and cattle are stall-fed continuously. The botanical composition on the feed offered depends on the season and the availability of the plant species. Generally, during the wet season, the diet consisted of 75% grasses and ground legumes and 25% shrub legumes and tree fodders. During the dry season, the diet consisted of 25% grasses and ground legumes and 75% shrub legumes and tree fodders. For NTFS, cattle were tethered and grazed during the day and stall-fed at night with the forage cut from the allocated plot.

One week before weighing, the amount and botanical composition of the feed offered and refusals were assessed. The daily feed requirement was estimated at 3% (DM) of average live weight plus 5% for ad libitum feeding.

The study gave the following 4-year results (Nitis et al. 1987):

- Live weight gain during the wet season was higher than during the dry season.
- TSFS cattle gained 8% less weight during the wet season and 17% more weight in the dry season than NTFS cattle.
- During the wet season, cattle at the higher stocking rate gained weight the same as cattle at the lower stocking rate. During the dry season, however, cattle at the low stocking rate gained 17% more weight than cattle at the high rate.
- Over the past 2 years, TSFS cattle gained 7% more weight, consumed 31% less forage, and were 35% more efficient in using forage than NTFS cattle. A similar trend was observed for cattle at the low stocking rate compared with those at the high stocking rate.

Feeding behaviour

Six cattle each from TSFS and NTFS were selected. For TSFS, cattle were observed in the stall; for NTFS, cattle were observed tethered. Cattle were observed for 12 h (0600–1800); the study was repeated three times. The following results were obtained (Nitis et al. 1987):

- Stall-fed TSFS cattle spent less time sniffing and eating the feed than tethered NTFS cattle.

- TSFS cattle spent more time ruminating and chewing than NTFS cattle.
- TSFS cattle spent more time urinating than NTFS cattle; times spent defecating were similar for both groups.
- TSFS cattle rested longer and more frequently (either standing or lying down) than NTFS cattle.

Gliricidia preference

When gliricidia was mixed with other forages, the consumption was up to 36% during the wet season and 45% during the dry season for TSFS cattle. For NTFS cattle, the corresponding values were 50 and 66%.

A Latin-square design (four feeding regimes, four cattle) was used to study the preference of cattle fed 100% gliricidia. The feed consisted of young leaves (top half of the leaves on the branch), old leaves (bottom half of the leaves on the branch), whole leaves (mixture of young and old leaves), and rachis (young branches with old and young leaves). The 28-day feeding experiment gave the following results (Nitis et al. 1987):

- Young leaves are less preferable than older leaves, presumably because of their astringent odour.
- Even though the consumption of young leaves is less than that of older leaves, because young leaves contain more CP, CP consumed is about the same.
- Cattle given the rachis feed spent time eating and turning over the feed to get at the older leaves and peel the skin off the young branches.
- Cattle weighing 184 kg (live weight) consumed 13–17 kg/day (fresh weight) gliricidia (1.63–2.17% of body weight).

Soil erosion

In July 1986, 18 months after TSFS establishment, a soil erosion study was initiated. Thirty galvanized iron pipes, each 150 cm long, were placed in the middle of the lots so that 125 cm of the pipe emerged above ground level. A mark was made by sawing a line on each pipe at ground level. This marking represented the starting point (zero reading) of erosion.

The slope selected varied from 8 to 10°. In TSFS, 15 lots (5 × 9 m each) were selected: three lots each of cenchrus, graham stylo, panicum, centro, and verano stylo. In NTFS, slopes similar to those TSFS plots were selected. In each NTFS plot, one to three locations were selected, each covering an area of 5 × 9 m (45 m^2). The study produced the following results (Nitis et al. 1988):

- In the year 1, the extent of erosion in TSFS was 6.56 mm; in NTFS, 12.00 mm. In the year 2, the extent of erosion in TSFS was 10.56 mm; in NTFS, 20.39 mm.
- Erosion in the grass lots was less than that in the legume lots.
- Among grasses, erosion in the cenchrus lots was less than in the panicum lots.

- Among legumes, erosion in the verano stylo lots was the least; graham stylo lots showed the most erosion.

Other studies

Mixed pasture

Because the two grasses (cenchrus and panicum) and three legumes (graham, verano, and centrosema) are grown individually in TSFS, a completely randomized block design with 12 treatments and 6 blocks was initiated in December 1985 to study the growth, yield, and persistency of the two grasses and three legumes in monospecific and mixed pasture. The 12 treatments included 2 grasses (cenchrus and panicum), 3 legumes (graham, verano, and centrosema), 3 cenchrus–legume (cenchrus–graham, cenchrus–verano, and cenchrus–centrosema), 3 panicum–legume (panicum–graham, panicum–verano, and panicum–centrosema), and one complete mixture (cenchrus–panicum–graham–verano–centrosema). Each plot was 5 × 6 m with a 30-cm raised bed in 0.53 ha of land with a 3–5° slope. Another 0.20-ha plot was allocated to compare with the native pasture.

The pasture was allowed to establish for 1 year and cutting was carried out twice a year; at the end of the dry season and at the end of the wet season. Samples (15 cm long) were collected using a 1.0-m^2 quadrat located in the middle of the plot. The whole plot was then cut. At the end of year 2, the following observations were made (Nitis et al. 1987):

- As monospecific pasture, verano stylo gave the highest yield and graham stylo gave the lowest.
- As mixed pasture, cenchrus–centrosema gave the highest yield and cenchrus–verano stylo gave the lowest.
- Wet-season yields were higher than those in the dry season.
- Grasses were more persistent than legumes during the dry season.
- The yield of the mixed pasture was not always higher that its monospecific counterpart.
- The yield of cenchrus was higher when it was grown on its own; panicum yield was higher when it was mixed with legumes.

Gliricidia germ plasm

At the end of the dry season, most of the young foliage of gliricidia was affected by black aphid. To study possible plant resistance, 15 provenances of *Gliricidia sepium* from seven Central American countries (provided by the Oxford Forestry Institute, UK) and one provenance of Indonesia (Bukit Bali) were tested in the field at Bukit. The 16 provenances have been grown in an area with rainfall varying from 600 to 3 500 mm and altitude varying from 0 to 1 100 mm. The location was selected so that the 16 provenances could be tested in alley cropping according to the method of Hughes (1987) and with the TSFS described by Nitis (1984). The alley cropping design is a completely randomized block arrangement with 16 treatments, 6 blocks (replicates), and 12 plants/replication. The three-strata fence design was a stratified, completely randomized block arrangement with 16 treatments, 12 blocks, and 10 plants/replication. Transplanting from the nursery was carried out on 1 December 1987, when the plants were 8 weeks old. Observation at 32 weeks after transplanting showed the following:

- Height, number of leaves, and branching habits varied among provenances.
- Some provenances produced more branches on the ground level, others produced more branches on the top half of the plants.
- Generally, more leaves were produced on the branches; in some provenances, the leaf number on the stem was similar to that on the branches.
- Stem elongation and leaf production not only depended on the provenance but were also affected by season.
- Percentage of leaf retained during the dry season on the branches was higher than that on the stems.
- Interestingly, the local provenance occupied ranking orders 3 to 8 of the 16 orders.

Productivity of TSFS

The 5-year (1984–1988) study clearly demonstrated the importance of the TSFS in terms of food, feeds, firewood, cattle, and conservation of the environment (Table 1).

Food

The lower grain yield of corn and soybean and lower tuber yield of cassava was due to the reduced plot size in TSFS (0.16 ha; that of NTFS was 0.25 ha).

Table 1. Productivity (kg dry weight/plot per year, unless noted) of TSFS and NTFS plots.

	TSFS plot (0.25 ha)	NTFS plot (0.50 ha)
Food	853	1 268
Straw	750	1 218
First stratum	455	—
Second stratum	310	—
Third stratum	15	—
Shrubs	—	132
Trees	—	2
Improved grasses	—	10
Native grasses	—	242
Firewood	1 049	475
Cattle live weight gain (kg/3 years)	186	166
Carrying capacity (cattle/ha)	4	2
Maximum live weight to carry (kg/head per plot)	300	200
Soil erosion (mm/2 years)	11	20

Source: Nitis et al. (1987), Nitis et al. (1988).

Feeds

- The higher straw production of NTFS was due to its larger area (0.25 ha vs 0.16 ha for TSFS).
- The grass and ground legume yields of TSFS were higher than those of NTFS. Of the 16 NTFS farmers, 12 planted cenchrus and panicum over 11 m^2/plot; in TSFS, this area was 45 m^2/plot.
- The 455.4 kg of grass and legume in TSFS occupied only 0.09 ha (5 060 kg/ha); the 241.9 kg of native grass in the NTFS occupied 0.25 ha (967.6 kg/ha).
- The yield of the shrubs and trees in TSFS was higher than that in NTFS. The NTFS plots were formerly surrounded by cactus. Of the 16 NTFS farmers, 12 have now replaced the cactus with gliricidia or leucaena, ficus, and lannea; the NTFS plots now also produce good yields of shrubs and tree fodders.

Firewood

When farmers cut the shrubs and trees in TSFS for fodder, the residual branches become useful for firewood (Fig. 1). The sources of the firewood are as follows:

- regular, daily cutting for forage and
- lopping every 3 years to remove the "head" formed by regular cutting at a certain height.

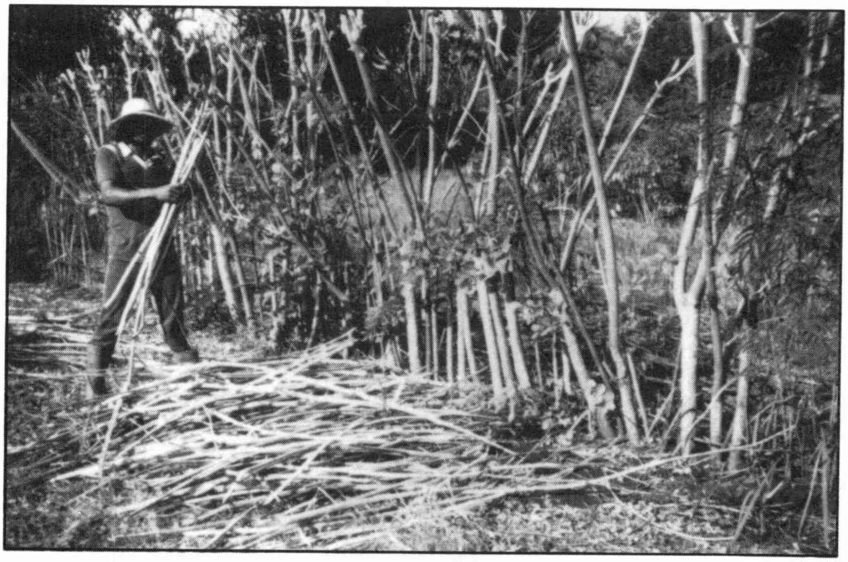

Fig. 1. Farmer harvesting *Gliricidia* and the resulting wood for fuel in the three-strata forage system in Bali.

Cattle

- TSFS cattle gained more weight and had a better feed-conversion ratio than NTFS cattle because of the better feed supply and feed quality.
- TSFS farmers spent less time managing cattle because the feed is always available and the animals are stall-fed close to the plots.
- TSFS land can carry 4 cattle/ha; NTFS land can carry only 2 cattle/ha.
- Forage in the TSFS plot (0.25 ha) can support cattle up to 300 kg; forage in the NTFS plot (0.50 ha) can support a cattle up to 200 kg.

Conservation of the environment

- Soil erosion in TSFS is less than that in NTFS because of the buffering effect of the forage and fodder in the first and third strata.
- TSFS creates a more pleasing environment; the plants and forage in the first, second, and third strata remain green almost all year.

Other farming activity

- Because flowering times for grasses, shrubs, and trees are different, it is possible to have a year-round pollen supply; this encourages bee keeping and honey production.
- Periodically, grass and legume seeds are scattered on the ground; white ants (termites) are also common in forage debris. These become carbohydrate and protein sources for Kampung chicken, which is raised extensively.
- The forage and fodder of the first, second, and third strata become sources of feed and shelter for snails during the wet and dry season; TSFS can encourage "backyard snail production."

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