PAPER • OPEN ACCESS

Sustainable development of smallholder crop-livestock farming in developing countries

To cite this article: S Ates *et al* 2018 *IOP Conf. Ser.: Earth Environ. Sci.* **142** 012076

Sustainable development of smallholder crop-livestock farming in developing countries

S Ates[1], H Cicek[2], L W Bell[3], H C Norman[4], D E Mayberry[5], S Kassam[6], D B. Hannaway[7] and M Louhaichi[1, 8]

[1)] Department of Animal and Rangeland Sciences, Oregon State University, Corvallis 97333, USA
[2)] FiBL, Department of International Cooperation, Switzerland
[3)] CSIRO Sustainable Agriculture Flagship, PO Box 102, Toowoomba, Qld 4350, Australia
[4)] CSIRO Agriculture and Food, Private Bag 5, Wembley, WA 6913, Australia
[5)] CSIRO Agriculture & Food, St Lucia QLD 4067, Australia
[6)] International Center for Agricultural Research in the Dry Areas (ICARDA), Cairo, Egypt
[7)] Department of Crop and Soil Science, Oregon State University, Corvallis 97333
[8)] International Center for Agricultural Research in the Dry Areas (ICARDA), Amman, Jordan
e-mail: serkan.ates@oregonstate.edu

Abstract Meeting the growing demand for animal-sourced food, prompted by population growth and increases in average per-capita income in low-income countries, is a major challenge. Yet, it also presents significant potential for agricultural growth, economic development, and reduction of poverty in rural areas. The main constraints to livestock producers taking advantage of growing markets include; lack of forage and feed gaps, communal land tenure, limited access to land and water resources, weak institutions, poor infrastructure and environmental degradation. To improve rural livelihood and food security in smallholder crop-livestock farming systems, concurrent work is required to address issues regarding efficiency of production, risk within systems and development of whole value chain systems. This paper provides a review of several forage based-studies in tropical and non-tropical dry areas of the developing countries. A central tenet of this paper is that forages have an essential role in agricultural productivity, environmental sustainability and livestock nutrition in smallholder mixed farming systems.

1. Introduction

A large proportion of rural poor populations across the world derive a major share of their livelihood from mixed farming systems. Smallholder farming enterprises have a critical role in rural development and supporting local food systems through integrating multiple agricultural value chains from vegetables and fruits to animal products. Additionally, they provide a number of social and agro-ecological benefits such as increased land use efficiency, improved biodiversity and access to affordable animal-source food for rural communities. These systems are threatened by population pressure, climate change, recurrent droughts and degradation of natural resources. These pressures are more acute in areas with climates that are marginal for existing practices [1]. In developing countries, the negative trends of unsustainable use of resources are often compounded by mismanagement, poor infrastructure, political instability, and ineffective socioeconomic policies. Addressing these issues will lead to improved sustainability, food security and rural livelihoods.

Forage plants sown for direct grazing, conservation or cover crops have a central role in agronomic sustainability and animal production in mixed crop-livestock farming systems. Benefits of forages include improved ruminant production, enhanced soil health and fertility, increased carbon sequestration, root disease management in cropping systems, increased biodiversity, and reduced economic risk through diversification [2] [3] . While the opportunities to expand the area of forage crops is limited due to the competition with field crops for land and water resources, increases in forage production may be possible through intercropping, alley cropping, or integration of legumes via crop rotation. Alternative fodder plants that are adapted to harsh climatic conditions and can be grown on lands unsuitable for cropping have significant potential for reducing the feed gap for livestock, improving animal health and contributing to food security and diversifying the income source of resource-poor farmers [4][5]. Revegetation of marginal land with perennials can lead to substantial increases in environmental health, including reduced soil salinity, increased carbon sequestration and reduced methane emissions from ruminants[6]. Developing varieties and management techniques for dual purpose (food-feed) legumes and cereals, cover crop grazing techniques, and intensifying cropping systems (by replacing fallows with feed and forage legumes) are promising options[7] [2][8]. Furthermore, increased efficiency in farming practices, value-added approaches, sound agricultural policies and specific value chain development are needed to improve access to inputs and markets for smallholders.

2. Integration of forage legumes into cropping systems

2.1 Forage legumes in crop-livestock farming in non-tropical dry areas

Forage legumes are essential to agricultural sustainability in dryland cereal-growing areas of the world where grazing livestock is a dominant enterprise. In dry areas where livestock are an integral part of the production system, forage legumes have increased crop yield and animal production [9] [2][8][10]. Legumes can be inserted into crop rotations in various ways depending on the production system, site-specific needs, farmer capabilities, and the amount of precipitation received. As conservation agriculture gains momentum in the dryland areas, there is potential for better integration of forage legumes into cereal based-cropping systems [11]. Based on one of three principles of conservation agriculture, diverse rotations, farmers are encouraged to grow forages legumes to avoid pest and weed pressures and improve soil quality. In addition, cereal–legume rotations extend the time during which the soil remains covered, and thus less prone to erosion and water loss.

In the dryland farming system of the Mediterranean region, several long-term barley- and wheat-based rotation experiments evaluated the value of forage legumes [11] [2]. Results demonstrated that forage and grain legumes are excellent alternatives to continuous cereal cultivation or cereal–fallow rotations in Mediterranean-type climate areas, leading to more efficient and sustainable cropping systems. The increased efficiency was also highlighted in a long-term study that compared yields and profitability of wheat (*Triticum aestivum* L.) when grown after wheat, fallow, a grazed mixture of medic species (*Medicago* spp.), and common vetch (*Vicia sativa* L.) cut for hay, over ten growing seasons in Syria [2]. It was reported that wheat after lentils were generally lower (2.22 t ha^{-1}) than after vetch (mean 2.56 t ha^{-1}) and after medic (2.40 t ha^{-1}). Inclusion of grain legumes in the rotations boosted profits significantly because of their high grain prices and valuable straw. Replacing fallow with vetch for hay production increased the average gross margin by US$126 ha^{-1} year^{-1}, and growing vetch for hay in rotation with wheat produced greater profit than continuous wheat, by $254 ha^{-1} year^{-1}. Similarly, on-farm trials in Tunisia have shown that replacing weedy fallows with forage legumes like vetch or sulla (*Hedysarum coronarium* L.) increased productivity under conservation agriculture [12]. The dry matter production (DM) of sulla averaged 6.2 t DM ha^{-1} with a crude protein content greater than 17%. Similarly, DM production of vetch and vetch/cereal mixtures ranged from 3.0 to 5.0 t DM ha^{-1}, as compared to weedy fallows that produced only 1.0 t DM ha^{-1}, illustrating the clear advantage of forage [12].

2.2 Forage legumes in crop-livestock farming in the semi-arid tropics

Research is also demonstrating the potential of using forage legumes in crop-livestock systems in the semi-arid regions of Eastern Indonesia. Livestock production in this region is constrained by low quality and unreliable availability of forage during the dry season, while yields of stapled cereal crops (rice and maize) can be increased by improved nitrogen supply. The herbaceous forage legumes, *Clitoria ternatea, Lablab purpureus* and *Centrosema pascuorum,* have shown to be well adapted and can be grown in either rotation or relay systems following either wet-season maize, or rice crops where irrigation water is limited or unreliable. Grain yields of a following maize crop were increased by 50% (1.4-1.6 t ha^{-1}) where legume was cut and removed, and by 90% (2.6-2.8 t ha^{-1}) where legume biomass was retained; the persistence of these benefits in subsequent years is being assessed [13]. This demonstrates that the transfer of nitrogen to subsequent crops is significantly diminished where legume material is cut and removed, as is often the case in smallholder cut and carry systems. Devising ways to enable livestock to graze the legumes directly is likely to enhance the N benefits provided by legumes to subsequent crops.

In addition to these herbaceous legumes, leguminous shrubs such as Leucaena can provide higher quality forage during the dry season in a variety of ways to improve cattle production. They can be used to enhance cattle fattening growth rates, but may also have value in other cattle systems. In some regions cattle are free-grazing, but a penned at night, where supplementing with small amounts of legume hay (1% of body weight) during the dry season enables cows to maintain body weight and condition, while unsupplemented cows lost 5% of their body weight. This is likely to have impacts on their subsequent fertility and calving interval, though this has not yet been shown. High mortality rates and low growth rates of Bali calves have been found in Eastern Indonesia, but this can be improved with grass hay and concentrate (18% CP), but this is expensive and complicated [14] [15]. Forage legumes have the potential as a cheaper alternative to a concentrate ration and preliminary studies have shown similar benefits for calf growth rates.

A series of experiments in Indonesia demonstrated that Bali (*Bos javanicus*), Ongole and Brahman (both *Bos indicus*) cows can all maintain weight on rice-straw based diets with small levels of supplementation [16] [17] [18]. Tree legumes such as *Gliricidia sepium*, *Leucaena leucocephela* and *Sesbania grandiflora* fed at approximately 0.3% liveweight (3-4 kg fresh weight) provided sufficient energy for maintenance, although the amount of supplement fed would need to be increased for cows in the late stages of pregnancy, lactating or being used for draught [19] . Even at low levels of inclusion in the diet, tree legumes comfortably meet the rumen degradable N requirements of cattle, without the risk or cost of feeding urea. Tree legumes provide a cheap and locally supplement for livestock throughout the year, including the dry season, and can be planted as living fences around the farmer's house or animal pens, where they can be harvested easily with little labour cost.

3. Utilizing trees and shrubs in forage systems

Alley cropping is a type of agroforestry in which trees or shrubs are planted simultaneously in rows with agricultural crops. It can be applied to improve forage production, mitigate drought, serve as a windbreak and capture windblown sediments in dry areas. The incorporation of trees or shrubs into farming systems may also have environmental advantages such as the lowering of the water tables causing secondary salinity, increasing functional diversity and improving soil stability[6][20][21]. Shrubs can be directly grazed or palatable tree fodder can be cut during autumn or winter-feed gaps. This can reduce supplementary feeding costs and increase paddock carrying capacity, enabling farmers to increase animal and crop production from the same land area[22][23]. Once mature, trees and shrubs can be pruned after grazing and used as a green manure or mulch to improve soil organic matter and improve crop growth. Grazing can enhance the production of woody material and proper pruning can increase the growth of green forage, extend plant longevity and improve fodder quality [23].

3.1 Alley cropping in productive soils

Saltbushes (*Atriplex nummularia* Lindl., *Atriplex halimus* and *Salsola vermiculata*) are commonly planted in arid areas of the southern Mediterranean region. They have many advantages because of their wide adaptability to harsh agro-climatic conditions and ability to grow for a longer period than many other crops and forage species. As they require little care after establishment, their production cost is low [24]. Atriplex species are used to fill the summer/autumn or early winter-feed gap typical of Mediterranean-type climates in southern Europe [25], southern Mediterranean [22] [26][27]. *Acacia cyanophylla* is often used in North Africa as it fixes nitrogen and provides edible leaves for livestock. In Central Asia, *Morus alba* L. and *Morus nigra* L. are commonly planted as hedgerows and their leaves can be fed to livestock. Another well-adapted species to the cold temperature of Central Asia is *Haloxylon ammodendron* that can tolerate direct grazing [28].

In south Mediterranean, studies on alley cropping systems showed that barley grain and straw yields had significant (20-100%) increases when cropped with *Atriplex halimus* L. in alley cropping systems as compared to mono-cropped barley [23]. In another study, the agronomic benefits of the cactus-barley alley cropping system were evaluated in Tunisia[29]. Similar to the results reported by [23], total biomass (straw plus grain) of barley cultivated between the rows of spineless cactus increased from 4.24 to 6.65 t ha^{-1} and the grain from 0.82 to 2.32 t ha^{-1} as compared to barley alone. These results were attributed to the change of the micro-environment created by alley-cropping with cactus, which created a beneficial 'wind breaking' role that reduced water loss and increased soil moisture. The barley crop stimulated an increase in the number of cactus cladodes and fruits, while the cactus increased the amount of root material, contributing to the soil organic matter.

The alley-cropping system with *Atriplex nummularia* L. also proved efficient in the semi-arid regions of Morocco (annual rainfall 200-350 mm). Barley was cropped using a seeding rate of 160 kg ha^{-1} between *Atriplex* rows planted at 333 plants ha^{-1}. Compared to the farmers' mono-cropping system, dry matter consumable biomass yield of *Atriplex* was significantly higher in the alley-cropping system and was more profitable than mono-cropping. [30] determined the net benefit from *Atriplex* monocropping and barley-*Atriplex* alley cropping over 15 years were 732 \$ ha^{-1} and 3,343 \$ ha^{-1}, respectively. The assessment of alley cropping system indicated that this technology is agronomically feasible and economically profitable. Thus, system should be extended on a larger scale in the agro-pastoral areas of North Africa and West Asia.

3.2 Use of shrubs in saline and arid areas

The area of human induced salinity is increasing rapidly and a major constraint to livestock production in many areas. Shallow water tables that are associated with poor irrigation practice is another major constraint to forage production. Only few plants can tolerate the combined stresses of salinity and waterlogging [31]. It is estimated that 5% of the world's land surface is cultivated salt-affected land, which includes 19.5% of irrigated agricultural land [32] [33]. A large proportion of salt-induced soil degradation occurs on land used by smallholder farmers, who are dependent on this resource for food and feed needs [34]. Considering the reliance of smallholder communities on saline waters and salt-affected soils for their livelihoods, direct and indirect impacts of salinity are often borne by the most vulnerable sectors of the population. In the past 15 years, there has been a concerted effort in to identify plants that can persist in saline, waterlogged and/or arid areas while providing nutrients for ruminants during critical feed gaps [35] . This work has largely focused on halophytic shrubs such from the Chenopodiaceae family as *Atriplex, Mariana and Rhagodia* species as they are naturally found in arid areas and are tolerant of salinity and aridity [36].

Halophytic shrubs are not ideal as a sole diet due to low to moderate digestibility of the organic matter, excessive salt and/or sulphur accumulation and production of plant secondary compounds such as oxalate or saponin [37] [38]. They tend to be used as a drought reserve or to fill annual feed shortages within grazing systems [39]. It is therefore recommended that farmers supplement ruminants grazing these shrubs with crop residues, hay or grain [21]. Despite these limitations, shrubs offer a valuable source of crude protein, sulphur, vitamin E and minerals within meat and wool production systems [40] [41]. There is ongoing work in Australia to select genotypes of *Atriplex nummularia* and *Rhagodia preisii* with higher nutritional value and improved 'palatability' to livestock [42]. Elite genotypes have been commercialized in Australia and testing of this material is being undertaken in Afghanistan, Tibet and Pakistan. Preliminary results from Afghanistan indicated that these elite genotypes can be successfully grown in marginal areas and have high potential to reduce the widespread feed shortage in Afghanistan [43].

4. Dual-purpose ('graze and grain') management of cereal crops

One area that has received little evaluation in smallholder production systems is the dual-purpose use of grain crops, where they are grazed during their early vegetative stage and later harvesting the grain and straw at maturity. Within a systems context, grazing crops can enable other pastures to be rested, thus increasing productivity of the whole-system[44] . This has been a common farmer practice in mixed farming systems in many developed countries [45] [7]. [7] summarize a range of reported studies and find consistently greater economic returns for dual-purpose cereal and canola crops compared with a grain-only option, particularly in dry seasons. However, the bioeconomic efficiency of dual-purpose management of cereal crops has not been widely assessed in developing world. Especially in the southern Mediterranean, where soil degradation, poverty and food insecurity are prevalent, adoption of dual-purpose management can provide desirable livelihoods outcomes.

Depending on the environment, grazing intensity and timing, and the resilience of plant species to grazing, satisfactory grain production can be obtained from dual-purpose cereal crops. Grazing at the tillering development stage does not necessarily reduce grain or fodder production [46] [47] and in some cases may even increase crop yields. For example, in a field trial in Tibet, [48] reported that cutting barley during the season to simulate grazing resulted in an increased grain yield of 0.9 t ha^{-1}. They hypothesized that the reduced plant height caused by cutting reduced lodging, which is a big problem for farmers in this region due to variety, management and seasonal conditions. Studies conducted in north-west China, have shown that cutting timing and height greatly influence the capacity of a wheat crop to respond after defoliation, with significant trade-offs between forage provision and grain yield recovery [49]. This seems to be particularly severe where crops have only a short period in which to recover while in longer season environments, the trade-off is less. Grazing of immature cereal crops (before stem elongation) may also have a positive impact on the nutritive value of the regrown forage material [50][51][52]. Given the widespread use of cereal straws in the diets of livestock in the West Asia-North Africa region, any improvement in the feeding value of these crop residues would have substantial effect on ruminant productivity.

The high nutritive value of immature winter annuals is aligned with the most productive period of growing lambs[44][53]. For example, [54] reported that crossbred lambs that grazed winter wheat had impressive liveweight gains (320-360 g/day) in Australia. Similarly, early spring liveweight gains of weaned merino lambs that consumed wheat (227 g head/d) and oat (221 g head/d) from tillering to booting stage were similar to the liveweight gains of lambs fed on a concentrate feed diet (256 g head/d) in Turkey [53]. At the vegetative phase, the energy content of dual-purpose crops is consistently measured at greater than 12 MJ ME/kg DM [35]. An issue when grazing crops is spatial variation in grazing intensity. Recent work in Australia found that preferred grazing areas could be manipulated through the use of a mineral supplement to attract sheep from over- to under-utilised areas of a wheat crop [55]. This could be a useful and practical grazing management practice in developing world where fencing to control grazing is not used in small segmented farms.

5. Crop residues and straw-based feeding

5.1 Stubble grazing, management and land tenure in WANA

Crop residues are a valuable livestock feed resource through the developing world. They are widely available, cheap to purchase, and can be stored for long periods to meet periods of feed shortages or reduce daily labour requirements for cutting feed for livestock. Over the last three decades, the feed gap has become more acute because of increased sheep numbers and expansion of cereal mono-cropping at the expense of food and forage legumes and rangeland resources in the south Mediterranean[9][56]. Consequently, cereal stubbles and straw have become the primary source of feed for small ruminants in the region [40][8]. Stubble grazing practices in the Mediterranean basin often lean towards intensive, high stocking rate methods, leaving soil barren. These intensive grazing practices also damage soil structure, create compaction, and lower the soils capacity to capture rainwater [57]. Although crop residues are perceived to be the essential nutrient source during the summer months, the dry matter intake and nutritional quality of the stubble decreases linearly with an increased number of grazing days and stocking rates [58][59]. Immediately after harvest, higher quality plant parts (leaves and some grain) are inadvertently left on the field. These higher quality materials have been shown to benefit livestock in liveweight gain, but animals consume these materials in a few weeks depending on the stocking rate [39]. Thus, the feeding value of stubbles declines over time and there is a point where the high-value components have been eaten and high fibre content of remaining stems will constrain intake to sub-maintenance levels. Provision of energy, protein and mineral supplements is required to utilize the remaining stubble.

5.2 Straw-based feeding in in the semi-arid tropics

Crop residues such as rice straw and maize stover often provide the bulk of livestock diets. However, they have low digestibility, and do not contain sufficient metabolisable energy (ME) or crude protein (CP) to maintain animal liveweight. Large amounts of research has been conducted to try to improve the feeding value of cereal straws through treatment with additives such as urea, ammonia and enzymes. These treatments have not been widely adopted by smallholder farmers because they are considered costly, labour intensive, technically difficult, or potentially dangerous to animal health [60]. Researchers in India have identified cultivars of maize, millet and sorghum that have higher quality stover without compromising grain yields [61] [62][63]. Supplements can be also used to increase the energy and protein content of livestock diets, but they need to be cost effective, easily accessible and practical to be adopted by farmers.

Crop by-products as such onggok (residue after starch extraction from cassava) or rice bran can also be used to provide additional energy to cattle fed rice-straw based diets. However[16] found that in Ongole cattle, feeding rice bran did not provide additional ME intake or liveweight gain compared to feeding gliricidia. It is important to note that while crop-residue based diets are sufficient for maintenance of livestock with low energy requirements, even with supplementation, they will not support high growth rates. However, by feeding rice straw to cows with low maintenance requirements, higher quality feed can be directed to high-value animals such as growing calves.

6. Socioeconomic and policy issues

Policies to promote the adoption of productivity-enhancing measures that will help improve the management of natural resources should be developed and enforced in developing countries. Improving the feed base through increased forage availability requires knowledge management, an understanding of the behavior of local communities, and the ability to communicate and reduce gender inequalities. Improved productivity and equitable access to inputs for crop-livestock production are needed to help increase household incomes as well as asset wealth and well-being through healthy livestock holdings. Recognizing that women play important roles within integrated crop and livestock production systems, greater attention must be focused on equitable access to knowledge and public and private services in the development of socially sustainable forage production systems. It is crucial to enhance national adoption of research-based recommendations through more effective linkages among national and international research systems, marketing and service providers, and farmers and consumers. Without proper technical backstopping and improved efficiency in crop-livestock production, producers in developing countries will not be able to compete with the more efficient foreign producers in either the domestic or export markets.

Understanding the whole-of-system implications of proposed technologies is also required. For example, studies have demonstrated that intensifying livestock production systems that require increased forage resources can have positive economic outcomes but can have negative impacts on food self-sufficiency and labour requirements [64]. The impact of particular technologies on both market and production risk is also often unexplored, this often requires whole-farm bio-economic modelling approaches. Furthermore, there is often a wide diversity of resource availabilities, capital access, skills and knowledge and production emphasis amongst small-holder producers. Hence, the impacts of particular technologies is likely to differ amongst them. For example, analysis of integrating forage legumes in Eastern Indonesia shows that farmers with access to underutilised land and more livestock are likely to benefit more [65].

Currently, lack of quality seed of improved forage varieties, poorly functioning seed and fodder markets, and biased national policy towards the production of strategic food grains and crops constrain the economic incentives for sustainable forage production and marketing. Redirecting subsidies on forage crops has provided successful outcomes for smallholder crop-livestock producers in various Mediterranean countries [66] [67]. Thus, public funds should be invested in supporting forage-based crop-livestock farming and research, including seed systems, rather than cereal mono-cropping or industrial-scale meat and milk production.

Reference

[1] World Bank 2008 World Development Report The World Bank Washington DC USA
[2] Entz M H, Baron V S, Carr P M, Meyer D W, Smith S and McCaughey W P 2002 Potential of forages to diversify cropping systems in the Northern Great Plains *Agronomy Journal* 94(2) 240-250
[3] Christiansen S, Ryan J, Singh M, Ates S, Bahhady F, Mohamed K, Youssef O and Loss S 2015 Potential legume alternatives to fallow and wheat monoculture for Mediterranean environments Crop and Pasture Science **66(2)** 113-121

[4] Masters D G, Revell D K and Norman H C 2010. Managing livestock in degrading environments In Sustainable improvement of animal production and health (N. E. Odongo, M. Garcia and G. J. Viljoen, eds.) pp. 255-267 Food and Agriculture Organization of the United Nations (FAO) Rome Italy
[5] Nefzaoui A, Louhaichi M and Ben S H 2014 Cactus as a tool to mitigate drought and to combat desertification *Journal of Arid Land Studies* **13** 121-124
[6] Barrett L E G, George R J, Hamilton G, Norman H C and Masters D G 2006 Multi-disciplinary approaches suggest profitable and sustainable farming systems for valley floors at risk of salinity *Australian Journal of Experimental Agriculture **45***(11) 1415-1424
[7] Bell L W, Moore A D, and Kirkegaard J A 2014 Evolution in crop–livestock integration systems that improve farm productivity and environmental performance in Australia *European Journal of Agronomy* **57** 10-20
[8] Porqueddu C, Ates S, Louhaichi M, Kyriazopoulos A P, Moreno G, del Pozo A, Ovalle C, Ewing M A and Nichols P G H 2016 Grasslands in 'Old World' and 'New World' Mediterranean climate zones: past trends, current status and future research priorities Grass and Forage Science **71**1-35
[9] Ryan J, Singh M and Pala M 2008 Long term cereal based rotation trials in the Mediterranean region: implications for cropping sustainability *Advances in agronomy* **97** 273-319
[10]Ates S, Keles G, Inal F, Gunes A and Dhehibi B 2015 Performance of indigenous and exotic× indigenous sheep breeds fed different diets in spring and the efficiency of feeding system in crop–livestock farming *The Journal of Agricultural Science* **153**(3) 554-569
[11] Loss S, Haddad A, Khalil Y, Alrijabo A, Feindel D and Piggin C 2015 Evolution and adoption of conservation agriculture in the middle east In Conservation Agriculture (pp. 197-224) Springer International Publishing
[12] Yau S K, Bounejmate M, Ryan J, Baalbaki R, Nassar A and Maacaroun R 2003 Barley–legumes rotations for semi-arid areas of Lebanon *European Journal of Agronomy* **19**(4), 599-610
[13] Hosang E J, Nulik J, Kanahau D, Abi Y and Bell L W 2016 Nitrogen contribution from forage legumes in maize farming system in West Timor Indonesia *Proceedings of the 2016 International Nitrogen Initiative Conference* Solutions to improve nitrogen use efficiency for the world 4 – 8 December 2016 Melbourne Australia www.ini2016.com
[14] Jelantik I G N, Mullik M L, Leo-Penu C, Jeremias J, Copland R 2008 Improving calf survival and performance by supplementation in Bali cattle *Australian Journal of Experimental Agriculture* **48** 954-956
[15] Jelantik I G N, Mullik M L, Leo-Penu C and Copland R 2010 Factors affecting the response of Bali cattle (*Bos sondaicus*) calves to supplementation prior to weaning Animal Production Science **50**(6) 493-496
[16] Antari R, Syahniar T M, Mayberry D E, Pamungkas D, Anderson S T and Poppi D P 2014 Evaluation of village-based diets for increasing the weight and condition of Ongole (Bos indicus) and Bali (Bos javanicus) cows in Indonesia *Animal Production Science* **54**(9) 1368-1373
[17] Antari R, Ningrum G P, Mayberry D E, Pamungka D, Quigley S P and Poppi P D 2014 Rice straw, cassava by-products and tree legumes provide enough energy and nitrogen for liveweight maintenance of Brahman (Bos indicus) cows in Indonesia *Animal Production Science* **54**(9) 1228-1232
[18] Syahniar T M, Antari R, Pamungkas D, Mayberry D E and Poppi D P 2012 The level of tree legumes required to meet the maintenance energy requirements of Ongole (Bos indicus) cows fed rice straw in Indonesia *Animal Production Science* **52**(7) 641-646
[19] Mayberry D E, Cowley F, Cramb R, Poppi D, Quigley S, McCosker K and Priyanti A 2016 Final Report 2016-16: Improving the reproductive performance of cows and performance of fattening cattle in low input systems of Indonesia and northern Australia Australian Centre for International Agricultural Research
[20] Le Houérou H N 1992 The role of saltbushes (Atriplex spp.) in arid land rehabilitation in the Mediterranean Basin: a review Agroforestry Systems **18** 107-148

[21] Norman H C, Silberstein R P and Byrne F 2008 Achieving profitable and environmentally beneficial grazing systems for saline land in Australia 12th meeting of the FAO-CIHEAM sub-network on Mediterranean pastures and fodder crops, "Sustainable Mediterranean Grasslands and their Multi-Functions", Elvas, Portugal; 01/2008
[22] Osman A E, Bahhady F, Hassan N, Ghassali F and Ibrahim T A 2006 Livestock production and economic implications from augmenting degraded rangeland with Atriplex halimus and Salsola vermiculata in northwest Syria *Journal of arid environments* **65**(3) 474-490
[23] Ghassali , Osman A E, Singh M, Norton B, Louhaichi M and Tiedeman J 2011 Potential use of Mediterranean saltbush (Atriplex halimus L.) in alley cropping in the low rainfall-cropping zone of northwest Syria. *Range Management and Agroforestry* **32**(1) 1-8
[24] Nefzaoui A, Ben Salem H and El Mourid M 2011 Innovations is small ruminants feeding systems in arid Mediterranean areas. In: "R. bouche, A. Derkimba, F. Casabianca (eds) New trends for innovation in the Mediterranean animal production" EAAP publication No 129 Wageningen Academic Publishers, ISBN 978-90-8686-170-5, ISSN 0071-2477. pp. 99-116
[25] Papanastasis V P, Yiakoulaki M D, Decandia M and Dini-Papanastasi O 2008 Integrating woody species into livestock feeding in the Mediterranean areas of Europe *Animal Feed Science and Technology*, **140**(1) 1-17
[26] Guevara J C, Silva Colmer J H, Estevez O R and Paez J A 2003 Simulation of the economic feasibility of fodder scrub plantations as a supplement for goat production in the north-eastern plain of Mendoza, Argentina *J. of Arid Environment* **53** 85-98
[27] Malcolm C V and Pol J E 1986 Grazing and management of saltland shrubs *J. of Agricultural* Western Australia **27** 59-63
[28] Clifton K and M Louhaichi 2015 Land Tenure, climate change and livestock mobility in Central and Southern Asian Grasslands Book chapter In P.K Ghosh, S.K. Mhanta, J.B. Singh, P.S. Pathak, Grasslands: A Global Resource Perspective (pgs. 347-362) New Delhi, India: International Grasslands Congress
[29] Alary V, Nefzaoui A and El Mourid M 2007 How risk influences the adoption of new technologies by farmers in low rainfall areas of North Africa? In: El-Beltagy, A. M.C Saxena and Tao Wang (eds) Human and Nature – Working together for sustainable Development of drylands. Proceedings of the 8th International Conference on Development of Drylands, 25-28 February 2006 Beijing China ICARDA, Aleppo, Syria. pp. 802-810
[30] Laamari A, Boughlala M and Chriyaa A 2005 Adoption and impact studies in Morocco In: H. Shideed Kamil and M El Mourid (eds) Adoption and impact assessment of improved technologies in crop and livestock production systems in the WANA region The development of integrated Crop/Livestock Production in Low Rainfall Areas of Mashreq and Maghreb Regions (Mashreq/Maghreb Project). ICARDA, Aleppo, Syria, 160 pp En pp 107-118
[31] Barrett-Lennard E G, Malcolm C V, Bathgate A 2003 Saltland Pastures in Australia – a Practical Guide, 2nd edition Sustainable Grazing on Saline Lands (a sub-program of Land, Water and Wool), 176 pp
[32] Flowers T J and Yeo A R 1995 Breeding for salinity resistance in crop plants: where next? Australian Journal of Plant Physiology. 22, 875-884
[33] Ghassemi F, Jakeman A J, Nix H A 1995 Salinisation of Land and Water Resources. CAB International, Wallingford, UK, 526 pp
[34] Qadir M, Noble A D, Schubert S, Thomas R J and Arslan A 2006 Sodicity induced land degradation and its sustainable management: Problems and prospects *Land Degradation & Development* **17**(6) 661-676
[35] Masters D G, Thompson A N 2016 Grazing crops: implications for reproducing sheep Animal Production Science **56** 655–668
[36] Norman H C, Masters D G and Barrett-Lennard E G 2013 Halophytes as forages in saline landscapes: interactions between plant genotype and environment change their feeding value to ruminants *Environmental and Experimental Botany* **92** 96-109.

[37] Norman H, Freind C, Masters D, Rintoul A, Dynes R, Williams I 2004 Variation within and between two saltbush species in plant composition and subsequent selection by sheep Australian *J. of Agricultural Research* **55** 999-1007
[38] Al Daini H, Norman H C, Young P and Barrett-Lennard E G 2013) The source of nitrogen (NH4+ or NO3–) affects the concentration of oxalate in the shoots and the growth of Atriplex nummularia (oldman saltbush) *Functional Plant Biology* **40**(10), 1057-1064.
[39] Ben Salem H, Norman H C, Nefzaoui A, Mayberry D E, Pearce K L and Revell D K 2010 Potential use of oldman saltbush (Atriplex nummularia Lindl.) in sheep and goat feeding *Small Ruminant Research* **91**(1)13-28
[40] Ben Salem H and Smith T 2008 Feeding strategies to increase small ruminant production in dry environments. *Small Ruminant Research* **77**(2) 174-194
[41] Pearce K L, Norman H C and Hopkins D L 2010 The role of saltbush-based pasture systems for the production of high quality sheep and goat meat *Small Ruminant Research* **91**(1) 29-38
[42] Norman H C, Hulm E and Wilmot M G 2015 Improving the feeding value of old man saltbush for saline production systems in Australia – a review Halophytic and Salt Tolerant Feedstuffs: Impacts on Nutrition, Physiology and Reproduction of Livestock. Eds Hassan M. El Shaer, Victor Roy Squires CRC press Taylor & Francis ISBN 9781498709200 - CAT# K24977
[43] ACIAR 2016 Forage options for smallholder livestock in water-scarce environments of Afghanistan http://aciar.gov.au/project/ah/2012/021
[44] Thomas D T, Moore A D, Norman H C and Revell C K 2015 Small effects of deferment of annual pastures through grazing spring wheat crops in Western Australia can benefit livestock productivity. *Crop and Pasture Science* **66** (4), 410-417
[45] Anderson W K 1985 Production of green feed and grain from grazed barley in Northern Syria. *Field Crops Research* **10** 57-75
[46]Fieser B G, Horn G W, Edwards J T and Krenzer E G 2006 Timing of Grazing Termination in Dual-Purpose Winter Wheat Enterprises1. *The Professional Animal Scientist* **22**(3) 210-216
[47] Cazzato E, Laudadi V and Tufarelli V 2012 Effects of harvest period, nitrogen fertilization and mycorrhizal fungus inoculation on triticale (× Triticosecale Wittmack) forage yield and quality *Renewable Agriculture and Food Systems* **27**(4), 278-286
[48] McNeill A, Wilkins J, Piltz J, Tashi N, Zhu Se, Tao J, Tsamyu H T, Brown C, Waldron S, Cummins J, Rose C, Coventry D and Paltridge N 2014 Integrated crop and dairy systems in Tibet Autonomous Region, PR China FR2014-04 Australian Centre for International Agricultural Research http://aciar.gov.au/publication/FR2014-04
[49] Tian L H, Bell L W, Shen Y Y and Whish J P M 2012 Dual-purpose use of winter wheat in western China: cutting time and nitrogen application effects on phenology, forage production and grain yield. *Crop and Pasture Science* **63**(6) 520-528.
[50] Francia E Pecchioni N, Li Destri N O, Paoletta G, Taibi L, Franco V, Odoardi M, Stanca A M and Delogu G 2006 Dual-purpose barley and oat in a Mediterranean environment. Field Crops Res. **99** 158-166
[51] Jacobs J L, Hill J and Jenkin T 2009 Effect of different grazing strategies on dry matter yields and nutritive characteristics of whole crop cereals *Animal Production Science* **49**(7) 608-618
[52] Keles G, Ates S, Coskun B and Koc S 2013 Re-growth yield and nutritive value of winter cereals. In Revitalising Grasslands to Sustain our Communities: Proceedings, 22nd International Grassland Congress, 15-19 September 2013 Sydney Australia (pp. 951-953) New South Wales Department of Primary Industry
[53] Keles G, Ates S, Coskun B, Alatas M S and Isik S 2016 Forage yields and feeding value of small grain winter cereals for lambs. Journal of the Science of Food and Agriculture
[54] Dove H, Holst P J, Stanley D F and Flint P W 2002 Grazing value of dual-purpose winter wheats for young sheep. *Animal Production in Australia* **24** 53-56
[55] Thomas D T, Moir B, Mata G, Toovey A and Flower K 2014 Use of supplementary feeding stations in a grazed wheat crop to increase the dispersion of sheep and their utilisation of the crop.

Proceedings of the Spatially Enabled Livestock Management Symposium 2014 18 November 2014 Hamilton New Zealand p 10

[56] Ates S, Feindel D, El Moneim A and Ryan J 2014 Annual forage legumes in dryland agricultural systems of the West Asia and North Africa Regions: research achievements and future perspective *Grass and forage science* **69**(1) 17-31

[57] Bell L, Kirkegaard J A, Swan A, Hunt J R, Huth N I, Fettell N A 2011 Impacts of soil damage by grazing livestock on crop productivity *Soil and Tillage Research* **113** 19–29

[58] Treacher T T, Rihawi S and Owen E 1996 Stubble grazing by sheep. In: Proceedings of the 2nd FAO Electronic Conference on Tropical Feeds Livestock Feed Resources within Integrated Farming Systems FAO Rome

[59] Moujahed N, Abidi S, Youssef S B, Darej C, Chakroun M and Salem H B 2015 Effect of stocking rate on biomass variation and lamb performances for barley stubble in Tunisian semi arid region and under conservation agriculture conditions *African Journal of Agricultural Research* **10**(50), 4584-4590

[60] Doyle P T, Devendra C and Pearce G R 1986 Rice straw as a feed for ruminants (International Development Program of Australian Universities and Colleges: Canberra)

[61] Anandan S, Khan A A, Ravi D, Rao M S B, Reddy Y R and Blümmel M 2013 Identification of a superior dual purpose maize hybrid among widely grown hybrids in South Asia and value addition to its stover through feed supplementation and feed processing *Field crops research* **153** 52-57

[62]Bidinger F R and Blümmel M 2007 Determinants of ruminant nutritional quality of pearl millet [Pennisetum glaucum (L.) R. Br.] stover: I. Effects of management alternatives on stover quality and productivity *Field crops research* **103**(2) 119-128

[63] Blummel M and Rao P P 2006 Economic value of sorghum stover traded as fodder for urban and peri-urban dairy production in Hyderabad India *International Sorghum and Millets Newsletter* **47** 97-100

[64] Komarek A M, Bell W, Whish J P, Robertson M J and Bellotti W D 2015 Whole-farm economic, risk and resource-use trade-offs associated with integrating forages into crop–livestock systems in western China. *Agricultural Systems* **133** 63-72

[65] Gabb S R, Bell L W, Basuno E, Prestwidge D, Prior J and Guppy C 2017 Whole-farm impacts of forage legumes in small-holder crop-livestock systems In Proceedings of the 2017 Agronomy Australia Conference, 24–28 September 2017 Ballarat Australia. www.agronomyconference.com

[66] Lloveras J, Santiveri P, Vendrell A, Torrent D and Ballesta A 2004 Varieties of vetch (Vicia sativa L.) for forage and grain production in Mediterranean areas. Cahiers Options Méditerranéennes **62** 103-106

[67] Demir N, and Yavuz F 2010 An analysis on factors effective in benefiting from forage crops support. *Scientific Research and Essays* **5**(15) 2022-2026