Livestock Research for Rural Development 18 (6) 2006 | Guidelines to authors | LRRD News | Citation of this paper

Livestock and poultry wastes management in Swaziland

Y Mijinyawa and B J Dlamini

Department of Agricultural and Environmental Engineering, University of Ibadan, Nigeria
mijin1957@yahoo.com
Department of Animal Production and Health, University of Swaziland, Luyengo campus, Swaziland
bjdlamin@agric.uniswa.sz

Abstract

A survey was carried out to assess the methods of livestock and poultry wastes management in Swaziland. The survey adopted the use of questionnaires which sought for information on the types of wastes generated, types of litter materials used, methods of wastes collection, pre-disposal wastes treatment, wastes utilization and possible effects of the wastes on the environment. Additional information was collected through personal communication and focused group discussions during the field trips while administering the questionnaires. Points of information gathering were commercial poultry and livestock farms, homesteads, dip tanks and feedlots. The data were analysed using percentages and frequencies, and the results presented in tables. Major solid wastes generated were from animal dung, poultry droppings and litters. Saw dust was the most popularly used litter material by about 38.7% of the large scale establishments while crushed corn cob was the least used by about 5.3%. Urine and spent water from washing in milking parlours and dip tanks constituted the liquid wastes.

Waste collection was by manual scrapping with spades, sweeping and floor washing using water hoses, and use of mechanical scrappers. Manual scrapping was the most predominant method for solid wastes collection. It was used by about 60% and 95.8% of the large scale establishments and homesteads respectively. Mechanical scraping was mainly used in the large scale establishments. Solid wastes were either collected and taken directly to the field for application or temporarily stored in compost pits and refuse dumps to undergo further decomposition. Only 33.3% of the homesteads had temporary dump sites. In most homesteads, kraal manure is removed during land preparation which eliminates the need for storage. About 33.3% of the large scale establishments had dump sites, 17.4% had compost pits while 16% had a combination of dumpsites and compost pits. Liquid wastes were disposed off on strip fields or adjacent streams. About 75.0% of the homesteads and 33.3% of the large scale establishments conveyed their wastes using wheel barrows while 4.2% and 26.7% respectively made use of a combination of wheel barrows and tractor trailers. All the homesteads and about 72.0% of the large scale establishments used solid wastes as fertilizers on their own farms. Liquid effluent was used for irrigation by about 5.3% of the large scale establishments. The ministry of agriculture and cooperatives is emphasizing the use of livestock wastes in fish farming while the biogas plants which were established to utilize some of the wastes have been abandoned.

Respondents admitted awareness of the dangers inherent in poor livestock and poultry wastes management but only a few admitted that their management techniques constituted any hazards to the environment. Solid wastes as presently generated, collected and utilized constitute no environmental threat but the liquid discharged to streams and wet cattle that wade through streams immediately after dipping are considered potential sources of pollution. Wastes are a potential source of biogas which is being effectively utilized in many countries. The abandoned biogas pilot schemes should be reactivated. Water quality assessment should be carried out on streams to which wastes are discharged and appropriate steps taken to prevent pollution. Oxidation ponds should be constructed near dip tanks and milking parlours. More extension work is required to educate the rural populace on the use of livestock wastes for fish farming.

Key words: beddings, biogas, dip tanks, kraal, livestock wastes, manure, Swaziland

Introduction

Swaziland is located between latitudes 30º 30'E and 32º 30'E of the Greenwich and between longitudes 25º 30'S and 27º 30' S of the Equator. The country is bounded in the north, west, south and south east by the republic of South Africa and to the north east by the republic of Mozambique. (Figure 1). The country covers a total area of 17,363km^2, out of which 17,203m^2 is land and the reaming 160km^2 is water.

Figure 1. Location map of Swaziland

The vegetation of the country varies from short grassland with forest patches in the Highveld region of the north to savannah in the Lumbobo region of the south. Annual rainfall varies from 500mm in the lowveld to a maximum of 2300mm in the highveld.Temperatures are between 11ºC and 29ºC. These conditions are favourable for the production of a number of crops and raising of animals. (Anon 2005a)

With a population of about one million people, the predominant occupation is agriculture. About 70 % of the populace are engaged in subsistence agriculture producing both crops and animals while agriculture accounts for about 17% of the country gross domestic products.(Wikipedia 2005) The major staple crops are maize, sweet and Irish potatoes, groundnut and beans while export crops include sugar and forest products. Animal raised include cattle, sheep, pig, goats and chicken.

Livestock and poultry play major roles in the social and economic life of the Swazis. The use of the cattle in the settlement of bride-price encourages a majority of the populace to keep the animal. Livestock serve as form of savings and have been used in some areas of the country as collateral. Meat, milk and eggs obtained from livestock and poultry provide the needed nourishment for a population under threat by the HIV/AIDS pandemic. Livestock and poultry wastes are good soil conditioners improving land productivity and can also be used as feed supplement. (Moyo 1985; Khumalo 1988; Kunene 1992).

The livestock and poultry industry is broadly divided into small and large scale production. Small scale animal keeping is practiced by small scale farmers and households on Swazi nation land and this group is reported to own about 77.0% of the total cattle population. Large scale livestock and poultry activities are carried out by some government farms, corporate organizations and private individuals mainly on title deed land. Small scale farmers own between one and 15 cattle while in commercial farms, the herd size could be up to 1,500. (FAO 2002).Table 1 shows the population of livestock and poultry in the country and their distribution among the four districts.

Table 1. Population of livestock and poultry in Swaziland by District

Animal\District	Hhohho	Manzini	Shiselweni	Lubombo	Total
Chicken	379,734	386,621	293,203	270,577	1,330,135
Cattle	142,906	123,050	143,415	112,889	522,260
Goat	72,213	71,219	65,144	65,000	273,576
Pigs	13,444	7,310	11,926	5,277	37,957
Ducks	10,405	9,210	8,268	8,758	36,641
Sheep	12,052	3,630	6,417	1,884	23,983
Other non-commercial poultry	4,047	5,676	3,237	4,573	17,533
Donkeys	3,334	1,644	3,516	3,311	11,805
Turkey	2,602	1,693	1,951	1,526	7,772
Horses	384	256	209	111	960
Mules	16	11	30	8	65

Source- Swaziland Central Statistical Office 2003

Subsistence animal raising takes place within the homestead and virtually every home has some animals. During the day, the animals are allowed to graze within and sometimes outside the homestead boundary and at night they are kraaled. During the off season periods, the animals are allowed to graze on crop fields, feeding on crop residues. This method of animal husbandry by subsistence farmers and homesteads constitute a nuisance as in most cases, the animals stray on to the high way causing vehicular accidents.

Commercial chickens are kept in deep litter and battery cage houses with concrete floors. Concrete floor pens are used for pigs. In order to aid waste management, litters from various materials are used on the concrete floor. At the feedlots, the animals are kept permanently in fenced yards. The commercial beef and dairy cattle farms, teaching and research centres have grazing fields where the animals spend most of their times and are only brought to the shed at the time of milking or medication.

Livestock wastes could either be solid or liquid. Livestock wastes are described as liquid if the moisture content is more than 96%, between 90 and 96% moisture content, it is described as slurry while if the moisture content is below 84%, it is considered as solid.(OFCN 2005). Livestock wastes are used as soil conditioner (Hermanson 2005; Hutchinson et al 2005.), materials for wall plastering and construction of granaries (Muller, 1980), fuel source either by direct combustion or converted to biogas (Jones et al 2005), livestock and fish feeding (Sevilleja et al 2005). Livestock wastes could also constitute nuisance through environmental pollution especially the liquid component which seep into the ground contaminating both surface and ground water

Where the wastes removed from a livestock unit are not immediately utilized, they should be adequately stored to minimize their harmful effect. (Charles 2005; NWP 2005). Depending on whether the wastes are solids or liquids, they could be stored in open stockpiles, covered stock piles, bunker and compost pits, roof structures, strip fields, holding ponds, pits, lagoons and storage tanks

One of the problems of livestock wastes that has attracted attention is their potential as pollutants in water courses. Many farms discharge their wastes to nearby streams and cannals which results in the destruction of aquatic life downstream. (University of Nevada 2005). Many legislations have been made to protect the environment and water courses while various improved methods of handling have been prescribed towards ameliorating the impact of wastes on the environment.(Ong 1991; North Carolina State University 1995; Anon 2005b; Nebraska Department of Environmental Quality 2005)

Both documentations and physical observation show that a large population of livestock and poultry are kept in Swaziland, and which expectedly generate a lot of wastes. Depending on the techniques of management, such wastes could either be assets or potential hazards to the environment where they are generated. It was therefore considered necessary to examine the wastes management techniques in Swaziland with a view to maximizing their benefits and promote a safe environment. Specifically, the research objectives were to identify the types of livestock and poultry wastes generated, the methods and facilities employed in the collection, the various methods of utilization, impact of the wastes on the environment, and make recommendations aimed at improving the handling methods and enhance utilization of the wastes.

Materials and methods

A questionnaire to adequately capture relevant information was designed. The information requested included the types of wastes generated, method of wastes collection, pre-disposal treatment, disposal method, utilization and possible impact on the environment. The questionnaire was pre-tested with selected livestock owners around Luyengo, who did not form part of the final respondents. This was done to ensure that the questionnaire did not contain any ambiguity and that it could easily be understood and completed by respondents.

Livestock and poultry are important components of virtually every homestead in Swaziland. 30 homesteads were randomly selected per region which gave a total of 120 households. The livestock unit of the ministry of agriculture and cooperative and the Swaziland dairy development board were consulted to obtain records in respect of large scale livestock and poultry establishments. A total of 75 establishments made up of 10 poultry farms, 15 dairy farms, 25 feedlots, five piggeries, 15 dip tanks and five training and research institutions were selected.

At least two visits were made to many of the respondents, first to deliver the questionnaire and second to retrieve it. During the retrieval visits, personal observation was also made while the respondents were further interviewed in order to obtain more information

Secondary information was also collected. The secondary sources included the University of Swaziland Library, the library of the Ministry of Agriculture and Co-operative, Mbabane and the Swaziland central Statistics office, Mbabane. Information was also sourced from the internet.

The data were analysed using percentages and frequencies, and the results presented in tables.

Results and discussion

Types of wastes

The types of wastes encountered in this study were substantially solids. Of the entire farms and homesteads surveyed, it was only in the dairy farms such as those of the University of Swaziland, Tibiyo and Masundvwini which have large milking parlours that significant amount of liquid wastes were generated. The liquid wastes from other livestock establishments which were mainly from regular activities such as washing did not amount to any significant quantity .The solid wastes comprised of faeces and beddings in enclosed buildings such as pens, deep litter and battery cage houses. In kraals, the wastes were almost completely faeces since no beddings are used. Four types of bedding or litter materials were identified during the study. These were grasses, saw dust, wood shavings and crushed corn cobs. The frequency of use of these materials is presented in Table 2.

Table 2. Types of bedding or litter materials used in livestock and poultry structures

Litter materials	Homesteads		Large scale establishments	
	f	%	f	%
No litter used	102	85.0	21	28.0
Grasses	12	10.0	17	22.7
Saw dust	6	5.0	17	22.7
Saw dust/ wood shavings	0	0	12	16.0
Crushed corn cob	0	0	4	5.3
Wood shavings	0	0	4	5.3
Total	120	100.0	75	100.0

Saw dust was the most popularly used material by about 38.7% followed by grasses used by 22.7% of the large scale establishments. Crushed corn cob and wood shavings were the least used by about 5.3% of the large scale establishments. About 85% of the homesteads did not use any litter material and the 15% who did, made use of grasses and saw dust. Saw dust is commonly available from the various timber industries such as the one located in Bhunya while grass is obtained free on most farms.

Wastes collection methods

Because of the management system which allows grazing during the day and kraaling at night, a substantial amount of the faeces is deposited on the crop fields and grazing land. These components of wastes are not usually collected but rather go directly to fertilize the soil. For those deposited within enclosed structures such as the kraal and poultry buildings, they must be removed to avoid health hazards.

Three principal methods of wastes collection were identified. These were the use of slopped floor with hose pipe, manual scrapping with spades and shovels, and the use of mechanical scrappers. Manual scrapping was the predominant method within the homesteads and large scale establishments as shown in Table 3.This method was employed by about 95.8% of the homesteads and 60.0% of the large scale establishments. Slopped floors were found in about 24.0% of the large scale establishments as against 4.2% in homesteads. Mechanical scraping was limited to large scale establishments which was dictated by the volume of wastes generated. About 16.0% of the large scale establishments used mechanical scrapping.

Table 3. Methods of wastes collection

Method	Homesteads		Large scale establishments	
	f	%	f	%
Manual scrapping with spades/shovels	115	95.8	45	60.0
Slopped floor	5	4.2	18	24.0
Mechanical scrapping	0	0	12	16.0
Total	120	100	75	100.0

In the kraals, manure is allowed to accumulate for over a period of time reaching as much as a year in some instances. It is then removed and depending on the quantity, can be transported to the field immediately to be applied or stored for a while before being taken to the field.

In poultry houses, the wastes are a mixture of droppings and beddings. As at the time of removal, the beddings have undergone sufficient decomposition and ready for land application. It is common to remove wastes from poultry houses directly to the field.

In stationery pens, wastes were removed by scrapping with shovel after which water jet is used to wash the floor. This is aided by

the use of a slopped floor. The water resulting from such cleaning is directed to a grassed field or discharged to a nearby stream.

Effective movement between the points of collection and either a temporary storage location or point of final use is a crucial factor in wastes management. Various alternatives are available from which a choice is made depending on the scale of operation, technical and economic situation of the farmer involved.Common methods of waste transportation within and outside the environment where they were generated included the use of wheel-barrows, tractor trailer, headpan or a combination of these. Table 4 is a summary of the conveyance methods adopted in the area of study. In the large scale establishments, 33.3% made use of wheel barrow, 33.3% used tractor trailers, 26.7% a combination of wheel barrow and tractor trailer, while only in 6.7% was the use of headpans adopted. In the homesteads, 75.0% depended on wheel barrows, 4.2% used tractor trailers while 20.8% depended on headpans.

Table 4. Wastes conveyance methods

Method	Homesteads		Large scale establishments	
	f	%	f	%
Manually using wheelbarrow	90	75.0	25	33.3
Tractor trailer	0	0	25	33.3
Use of wheelbarrow and tractor	5	4.2	20	26.7
Manually using Head pans	25	20.8	5	6.7
Total	120	100.0	75	100.0

Wastes storage and disposal

When wastes are removed from the point of generation, they may be disposed off immediately or stored temporarily. During such storage periods, the wastes may undergo further treatment to either reduce its harmful effect or value addition. For this to be effectively done, adequate structures must be provided on the farm. During this study, the structures found in use for this purpose were compost pits and temporary dump sites. These are presented in Table 5.

Table 5. Wastes handling facilities

Facility	Homesteads		Large scale establishments	
	f	%	f	%
Temporary dump site	40	33.3	25	33.3
None	80	66.7	25	33.3
Compost pit	0	0.0	13	17.4
Temporary dump site/ compost pit	0	0.0	12	16.0
Total	120	100.0	75	100.0

About 33.3% of the large scale establishments have temporary dump sites, 17.4% have compost pits while 16.0% use a combination of the two. In some large scale establishments especially the poultry farms, the wastes are bagged at the time of collection and taken to the point of sale. Such farms have neither compost pits nor dumpsites. This was observed in about 33.3% of the large scale establishments.

In most of the homesteads, the wastes are not removed from the kraal until it is time for land preparation when it is removed and taken straight to the field. This account for the low number of dump sites among this group. Dump sites were only observed in 33.3% of the homesteads.

The liquid wastes generated by the dairy farms and from dip tanks are discharged directly onto the neighbouring streams or field. There was no evidence of any treatment of the effluent before it is discharged onto the stream.

Wastes utilization

Although described as wastes because of the form in which it is at the time of generation, livestock and poultry wastes have many useful applications. Table 6 summarizes the various ways by which wastes were utilized among the farmers in the area of study.

Table 6. Methods of livestock and poultry wastes utilization

Utilization	Homesteads		Large scale establishments	
	f	%	f	%
Solid wastes are used as manure on the farm fields	120	100.00	54	72.0
Solid wastes are sold to be used for land application	0	0.0	29	38.6
Solid wastes are left at the dump to decompose	0.0	0.0	25	33.3
Solid wastes are conveyed to communal dumpsite	0.0	0.0	13	17.3
Solid wastes given freely to neighbourhood farmers for land application	23	19.2	13	17.3
Liquid wastes is directed to fields for irrigation	0	0.0	4	5.3
Solid wastes are dried and re-used as part of animal feed	0	0.0	4	5.3

The primary utilization of all forms of livestock and poultry wastes in Swaziland is as fertilizer. About 72.0% of the large scale establishments and all the homesteads use part or all of the wastes generated as fertilizer in their own farms. Kraal manure is regularly collected and used on the field. The use of kraal manure for land application is encouraged by the proximity of fields to the kraals which reduces the burden of transportation. Many of the farms utilize all their wastes and don't sell while a few others and individuals, who generate more than their requirements, sell to other farmers. As at survey period, a 50kg bag of poultry wastes sold for US $0.50.It was however observed that in some of the big feedlots, most of the manure was not utilized and was left there over a number of years to accumulate. Liquid wastes were used for irrigation in about 5.3% of the large scale farms while in about the same number, solid wastes were dried and re-used as part of animal feed.

The fishery department of the ministry of agriculture and cooperative is currently promoting the use of livestock wastes in fish farming. This is being pursued through teaching farmers how fish ponds can be fertilized using livestock wastes. Preference is given to manure from monogastric animals rather than ruminants since the manure from the monogastrics is quite high in nutrients. (MOAC 2005).The ministry embarked on this programme as one way of alleviating poverty within the kingdom and the expected benefits are that it will help recycle organic wastes making the wastes from one enterprise as an input to another, it will prevent pollution which would have been caused by dumping the wastes on surroundings, the system will maximize the use of space as the livestock building such a poultry house can be built on the pond wall. (MOAC 2005)

Attempts to utilize livestock wastes in biogas production in Swaziland were initiated in 1975.Coordinated by the Appropriate Technology Unit of the Women in Development Programme; three pilot biogas production plants were constructed. (Ndlandla 2005).These were located at the Women in Development training centre at Ntonjeni, the head office of the Women in development at Mvutshini and the third was located at Mpini. The scheme was not embraced as expected by the rural communities who were targeted to be the principal beneficiaries for a number of reasons. The cost of construction of the digester which was put at about US $750.00 was considered too exorbitant and beyond the reach of the rural dwellers. Because of the dry condition of some areas, the cattle dung gets dried quickly and had to be rewetted before being loaded into the digester. Between 30 to 50 liters of water was required for this purpose. This was considered problematic in an area where the scarcity of water has driven people to depend on dews for domestic water need. The energy output was considered inadequate to meet domestic requirement. Attempts to increase energy output through the integration of cow dung and human wastes as raw materials was resisted as that was considered unacceptable to the Swazi culture. The project is presently abandoned.

Impact of livestock and poultry wastes on the environment

Because of the population and distribution of livestock and poultry throughout the country, it was considered necessary to examine if the wastes generated posed any possible hazards to the environment. Indices which were considered included proliferation of dumping sites and water pollution. A number of questions on this aspect were put to respondents of large scale establishments since that is where significant quantities of wastes were generated. Their responses are presented in Table 7. Physical observation of the environment was also made in order to verify the claims of some of the respondents.

Table 7. Report of impact assessment

	Yes		No	
	f	%	f	%
Your waste disposal method constitute a threat to the environment	8	10.6	67	89.3
Your waste disposal method is a potential source of pollution to nearby stream	4	5.3	71	94.7
Your waste disposal method is a potential source of	0	0.0	75	100.0

pollution to play grounds in the neighborhood				
Your waste disposal method constitute a barrier in the free flow of water in nearby streams	0	0.0	75	100.0
The offensive odour emanating from your wastes disposal method put neghbours at discomfort.	4	5.3	71	94.7

All the respondents claimed to be aware of the danger inherent in improper management of livestock and poultry wastes but only 10.6% admitted that their waste disposal method constituted a threat to the environment. About 5.3% admitted that their wastes disposal method constituted a potential source of pollution of water in nearby rivers while 5.3% agreed that the odour from their wastes disposal puts neighbours at discomfort.

Solid livestock and poultry wastes did not constitute any major hazards. Swaziland in general has environmental regulations which forbids the indiscriminate dumping of refuse of all sorts in unauthorized places (SEA 2001) and by virtue of the land tenure system, there are no unprotected pieces of land where refuse can be indiscriminately dumped. Solid wastes management is therefore confined within the homesteads or boundaries of the establishments. The high demand for the solid wastes for farmlands ensures that most of the solid wastes are used and no left-overs to create environmental hazards.

Liquid wastes from milking parlours and dip tanks are in most cases discharged to streams. At inception, proximity to streams was considered an advantage in the location of dip tanks. This was to provide water needed at the dip tanks and an easy means for the disposal of spent water from the dip tank. However, present awareness shows that the spent water which is discharged into these streams is a potential source of pollution. It was also observed that after dipping and when the animals are still wet, they wade through the adjacent stream depositing some of the treatment chemicals into the stream water. In a study of the destination of nutrients, organic matter and biological components of manure and urine in an out wintering situation, deposites of manure and urine were observed in a stream through which animals walked as they go for a drink. (CIAS 2005).

Although the scope of this study and time constraint did not permit water analysis, it is believed that the discharge of liquid wastes to streams is a potential hazard as the downstream is a source of domestic water. Water scarcity has attained a serious dimension in Swaziland in recent times such that households have to result to the use of water from any source.

Conclusions

- Livestock and poultry play major roles in the social and economic life of the Swazis. The use of the cattle in the settlement of bride-price encourages a majority of the populace to keep the animal. Livestock and poultry serve as form of savings and have been used in some areas of the country as collateral. Meat, milk and eggs provide the needed nourishment for a population under threat by the HIV/AIDS pandemic. Livestock and poultry wastes are good soil conditioners improving land productivity and can also be used as feed supplement. Animals are widely kept by both small scale farmers in homesteads and at commercial level in dairy farms, feedlots, teaching and research centres and in ranches.
- Wastes are mainly faeces and beddings. Except in the dairy farms where liquid wastes are generated from the milking parlours and at dip tanks, most of the wastes generated are of solid type. Litter materials are from grasses and saw dust/wood shavings.
- Wastes collection from animal units are by manual scrapping using diggers and spades, sloped floor with a water hose and in a few cases mechanical scrappers. Temporary dumpsites and compost pits serve as storage units for livestock and poultry wastes. Conveyance of solid wastes between points of generation and use is accomplished with wheel barrow, head pans and tractor trailer.
- The primary use of livestock and poultry wastes in Swaziland is as a fertilizer on agricultural land. Those farms that produce in excess of their requirement dispose the surplus off through sales or as gift to neighboring farms. A 50kg bag of poultry wastes sold for US $0.50. At present, efforts are on to popularize the use of livestock and poultry wastes for fish farming. An attempt has been made to produce biogas from livestock wastes but the scheme for logistic reasons was abandoned.
- Using the emergence or proliferation of refuse dumps and water pollution as indices of environmental impact, there appears no evidence of major environmental pollution arising from solid wastes but the liquid wastes from dairy farms and dip tanks discharged to streams is considered a potential hazard of water pollution.

Recommendations

- The discharge of liquid wastes by some dairy farms and dip tanks is considered a potential source of pollution which could affect the users of the downstream and aquatic life. Water quality assessment should be carried out on these streams especially now that the increasing water scarcity in the country is compelling more families to depend on water from streams. All available sources of water must be of good quality to meet human requirement.

- Where proximity to streams is still considered an advantage in the location of dip tanks, the spent water from the dip tanks should not be discharged directly to streams while the management should be such that disallow the cattle from having access to the stream while still wet. More time should be spent in the draining yard before the animals are allowed to leave the dip tank. An oxidation pond can be dug to hold the spent water for sometimes before it is discharged to the stream. Similar ponds should be dug around the milking parlours to retain the liquid wastes before discharge onto the streams and field.

- The successful use of livestock wastes in fish farming will be an additional source of income for the rural poor and improve their diet. It will be a catalyst in the attainment of the food security goals of the kingdom. Extension services in the dissemination of information in respect of the use of livestock wastes for fish farming among the rural farmers should be intensified.

- There are a lot of unused livestock wastes especially in some of the ranches which could be used in the production of biogas. It is recommended that the abandoned biogas project be reactivated. Extensive research should be carried out on the pilot project before being introduced to the beneficiaries. Such research efforts should address the earlier problems which led to the abandonment of the project and new ones which are likely to militate against its acceptability.

References

Anon 2005a Climate information for Swaziland - Climate Zone . Retrieved January 30, 2006, from http://www.climate-zone.com/climate/swaziland/

Anon 2005b Legislation for Management of Wastes. Hong Kong Environmental Protection Department. Retrieved January 26, 2006 from http://www.epd.gov.hk/epd/english/laws_regulations/envir_legislation/leg_waste.html

CIAS (Centre for Integrated Agricultural Systems) 2005 Outwintering dairy cattle: manure management issues. Retrieved November 29, 2005 from http://www.cias.wisc.edu/archives/1998/02/01/outwintering_dairy_cattle_manure_management_issues/index.php.

Charles D F 2005 Storing Poultry Litter. Retrieved April 8, 2005from http://muextension.missouri.edu/explore/envqual/wq0212.htm.

FAO 2002 Crop and food assessment mission to Swaziland. Retrieved November 29, 2005 from http://www.fao.org/documents/show_cdr.asp?url_file=/docrep/005/y6815e/y6815e00.htm.

Hermanson R E 2005 Managing Livestock Manure to Protect Groundwater. Washington State University Cooperative Extension. Retrieved September 27, 2005 from http://www.whatcomcd.org/FarmAssist/BMP/LivestockOps.htm

Hutchinson M L, Walters L D, Avery S M, Munro F and Moore A 2005 Analyses of Livestock Production, Waste Storage, and Pathogen Levels and Prevalences in Farm Manures. Applied and Environmental Microbiology, March 2005, p. 1231-1236, Vol. 71, No.3. Retrieved November 29, 2005 from http://aem.asm.org/cgi/content/full/71/3/1231.

Jones D D, Nye J C and Dale A C 2005 Methane Generation from Livestock Waste. Retrieved July 15, 2005 from http://danpatch.ecn.purdue.edu/~epados/swine/pubs/methane.htm

Khumalo N A 1988 Effect of kraal manure on root-knot nematode and pod yield in Okra. Unpublished B.Sc. Project, University of Swaziland.

Kunene N W 1992 The contribution of livestock to the cash economy of Swaziland Nation Land (SNL) farmers of area between Nkoyoyo and Nkaba in the Hhohho region of Swaziland. Unpublished B.Sc. Project, University of Swaziland

MOAC (Ministry of Agriculture and Co-operative) 2005 Agriculture-Aquaculture integrated systems: A training manual. Ministry of agriculture and cooperatives. Mbabane

Moyo H V 1985 A review of some of the possible uses of poultry manure and a study of its use as a feed supplement for growing rabbits. Unpublished B.Sc. Project, University of Swaziland

Muller Z O 1980 Feed from Animal wastes: state of knowledge. FAO Animal Production and Health Paper 18.Rome. http://www.fao.org/DOCREP/004/X6518E/X6518E00.htm

NWP (National Water Program) 2005 Animal Waste Management. Retrieved November 29, 2005 from http://www.uaswaterquality.org/themes/animal/default

Ndlandla W 2005 Personal communication. Community Development Officer, Appropriate Technology Unit, Women in Development,

Mvutshini, Swaziland.

Nebraska Department of Environmental Quality 2005 Fact Sheet on 1999 Livestock Legislation. Retrieved January 25, 2006 from http://www.deq.state.ne.us/Priority.nsf/pages/factsh2

North CarolinaState University 1995 Water Quality and Waste Management rules for livestock farms in North Carolina. Retrieved January 25, 2006 from http://www.soil.ncsu.edu/publications/Soilnote/note03.pdf

OFCN (On-Farm Composting Network) 2005 Composting Livestock Wastes. Retrieved April 8, 2005 from http://www.farmcompost.com/default.asp?page_id=188

Ong H K 1991 Goals, regulations and information needs for waste-managed centralized pig farming areas: a Malaysian perspective. Pig News and Information **12**: pp. 541-544.

Sevilleja R, Torres J, Sollows J and Little D 2005 Using animal wastes in fishponds. Retrieved August 12, 2005 from http://www.fao.org/documents/show_cdr.asp?url_file=/DOCREP/005/Y1187E/y1187e34.htm

SwazilandCentral Statistical Office 2003 2002/2003 Swaziland Census of Agriculture. Central Statistical Office, Mbabane.

SEA (Swaziland Environment Authority) 2001 National Solid wastes management strategy for Swaziland. Mbabane.

University of Nevada 2005 The risk of water contamination from livestock waste management. Retrieved November 29, 2005 from http://www.unce.unr.edu/water/pdf/livesp.pdf

Wikipedia 2005 Economy of Swaziland. Retrieved October 11, 2005 from http://en.wikipedia.org/wiki/Economy_of_Swaziland

Received 2 February 2006; Accepted 10 May 2006; Published 23 June 2006

Go to top