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RESEARCH ARTICLE

Evaluation of Manure Management in Dairy Cattle Farms: The Case of İzmir - Tire (Turkey) Region [1]

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Summary

The objective of this research is to evaluate the current manure management systems in dairy cattle farms, which are the members of Tire Dairy Cooperative, in Tire-İzmir Region. In this context; characteristics of farms, manure management systems and their statistical interactions were determined. Also, methane emissions through manure management were estimated for two different approaches of Intergovernmental Panel on Climate Change (IPCC) and SWOT analyze for manure management in region was done. According to results of the research, it is noticed that farmers do not care about technical standards and legal regulations on planning the barn placement and storing the manure. It is determined that 74% of the examined farms use mechanization possibilities to collect the manure from paddocks. In 78% of the farms manure is stored as a bulk inside or outside of the farm, in 16% of the farms it is stored on paddocks and in 6% of the farms it is stored in a pit. In 99% of the farms, manure is used as fertilizer on fields without taking precautions for fermentation and also it is burned directly in 1% of the farms. Statistical analyses show that, manure collection and storage practices have significant interactions with farm characteristics while manure usage practices have no significant interactions with farm characteristics. Methane emissions for the region were calculated 0.2 Gg year-1 for the first approach and 0.03 Gg year-1 for the second approach. SWOT analyze shows that, manure management practices and infrastructure are better in big farms and the cooperative may make a significant contribution to usage of modern systems in the region.

Keywords: *Dairy cattle farms, Barn, Manure management, Methane emissions, Tire*

Süt Sığırcılığı İşletmelerinde Gübre Yönetiminin Değerlendirilmesi: İzmir - Tire Yöresi Örneği

Özet

Bu araştırmada, İzmir-Tire yöresinde kooperatife kayıtlı süt sığırcılığı işletmelerinde mevcut gübre yönetim sistemleri ve uygulamalarının değerlendirilmesi amaçlanmıştır. Bu kapsamda işletme özellikleri ile gübre yönetim sistemleri ve aralarındaki istatistiksel ilişkiler araştırılmıştır. Ayrıca gübre yönetiminden kaynaklanan metan gazı emisyon değerleri Hükümetler Arası İklim Değişikliği Paneli (IPCC) Rehberinde belirtilen iki ayrı yaklaşıma göre tahminlenmiş ve gübre yönetim uygulamalarına ilişkin GZFT analizi yapılmıştır. Araştırma sonuçlarına göre, işletmelerin ahır yeri seçimi ve gübre depolamada, teknik standartlar ve yasal düzenlemelerde belirtilen esaslara uymadığı anlaşılmıştır. İşletmelerin %74'ünde gübre toplamada mekanizasyon kullanıldığı belirlenmiştir. Gübrenin, işletmelerin %78'inde işletme içinde ya da dışında yığın halinde, %16'sında padoklarda ve %6'sında ayrı bir gübre çukurunda depolandığı anlaşılmıştır. Gübrenin, işletmelerin %99'unda olgunlaştırılması için gerekli önlemler alınmadan tarım arazilerinde kullanıldığı, %1'inde ise aynı zamanda yakacak olarak değerlendirildiği saptanmıştır. İşletme özelliklerinin gübre toplama ve depolama uygulamaları üzerinde istatistiksel açıdan önemli bir etkiye sahip olduğu, gübre değerlendirme uygulamaları üzerine etkisinin ise istatistiksel olarak önemli olmadığı belirlenmiştir. Araştırma alanındaki metan gazı emisyonu birinci yaklaşıma göre 0.2 Gg yıl-1, ikinci yaklaşıma göre ise 0.03 Gg yıl-1 olarak belirlenmiştir. Yapılan GZFT analizi sonuçları yöredeki gübre yönetim altyapı ve uygulamalarının büyük kapasiteli işletmelerde daha iyi olduğunu, gübrenin biyokütle olarak değerlendirilmesine ilişkin modern uygulamaların gerçekleştirilmesinde kooperatif şeklindeki örgütlenmenin önemli bir katkı sağlayabileceğini göstermiştir.

Anahtar sözcükler: *Süt sığırcılığı işletmesi, Ahır, Gübre yönetimi, Metan emisyonu, Tire*

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INTRODUCTION

The main aims of manure management in dairy cattle farms are to preserve the animals' health, to reduce to minimum water and air pollution, to keep the spread of pests under control, to conform to current legislation, and to balance fixed investment, operation costs, work force and the use of feed [1-2].

It has been stated that manure management cannot be standardized Europe-wide because of differences in such factors as housing, manure management practices and climate [3]. Manure management practices in Europe and Asia have been the cause of serious environmental pollution, and the manure produced has not been used efficiently in the production of agricultural fertilizer or biogas [4]. Morse Meyer et al.[5] have found that in farms in California too, manure management practices cause environmental pollution and that not enough use is made of the manure.

In Turkey, the capacity of dairy cattle farms has risen in recent years, and the resultant increase in manure production has created a serious problem of environmental pollution. In order to solve this problem, it is necessary to apply the basic principles, technical standards and legal requirements relating to the choice of place of housing and manure management in dairy farming [6-11]. In addition, it is necessary to dispose of and recycle this animal manure in an environmentally acceptable way, including the use of biomass-energy systems [12-14].

Methane gas emissions from animal production are estimated either by direct measurement techniques or by the use of various methods of estimation [15]. Inter-governmental Panel on Climate Change (IPCC) has two tiers to estimate the methane emissions from manure management. Approach 1 is a simplified approach that relies on default emission factors drawn from previous studies. The Approach 1 approach is likely to be sufficient for most animal types in most countries. Approach 2 is a more complex approach that requires country-specific information on livestock characteristics and manure management practices. The Approach 2 approach is recommended when the data used to develop the default values do not correspond well with the country's livestock and manure management conditions. Because cattle characteristics vary significantly by country, it is recommended that countries with large cattle populations consider using the Approach 2 approach for estimating methane emissions from cattle and cattle manure [16]. In Turkey, use of the first approach of the methodology proposed in the IPCC guidelines has been adopted due to lack of the specific data [17]. Total methane gas emissions from manure management have been rising recently: they are stated to have reached 52.55 Gg in 2006, 78% of which is from cattle manure [18].

Biomass, as well as being an economic and sustainable source of energy, can also help with the country's aim of reducing greenhouse gas emissions. The conversion of biomass in the production of biogas from manure is a common practice in the world today. In Asian countries like India and China, small biogas plants are in operation, while in countries such as Germany, Britain, the Netherlands and Denmark biogas plants with a larger production capacity are more widespread. These kinds of plants are set up either on large animal-rearing farms or in areas with intense animal husbandry [19,20]. However, deficiencies in the technical and legal arrangements and a lack of information have resulted in Turkey still being at the development stage in bioenergy production [21,22].

İzmir has approximately 30% of the cattle population of Aegean Region and in İzmir the biggest portion is belongs to Ödemiş (38%) and Tire (19%) districts relatively [23]. It is of great importance in terms of providing a sustainable environment for research to be carried out on manure management practices and the resulting methane emission on the dairy farms existing in the area, and to determine the potential as biomass of the manure produced.

In this study, a determination was made of manure management systems and their operation in the Tire district of Izmir province, which contains a significant share of the dairy farming industry of Turkey and which at the same time is organized into cooperatives. This included making an assessment based on the relative standards and legal provisions relating to infrastructure and practices regarding manure management on selected farms, their operational characteristics, manure management practices, and greenhouse gas emissions, and suggestions were made for enabling a sustainable environment.

MATERIAL and METHODS

The study was carried out on selected dairy cattle farms which were members of the Tire Dairy Cooperative in the Tire district of Izmir province. The number of farms was calculated as 65, with a 90% safety margin, from among the farms registered with the cooperative, on the basis of proportional sample volume [24,25]. These farms were selected randomly. Characteristics of the farms (education level of the farm manager, year of establishment, the number of animals, housing type, system and location) and manure management practices (collection, storage and treatment) were determined in questionnaire and survey studies performed in 2008.

Statistical evaluation of the relationship between farm characteristics and manure management practices was performed using SPSS, descriptive statistics were calculated in determining distribution, and correlation analysis was performed to determine the relation between

manure management practices and farm characteristics. In comparing farm characteristics, the farms were grouped separately according to their animal numbers and the year of establishment. In addition, SWOT analysis was carried out with regard to manure management on the farms, determining the strengths, weaknesses, opportunities and threats involved in current manure management.

The values of methane gas emissions arising from manure management on the farms were calculated using two different approaches set out in the guidelines of the Intergovernmental Panel on Climate Change [16,26].

In the first approach, Annual Total Emission values ($ATE_{1st\ approach}$) (Gg $year^{-1}$) were calculated by means of Equation 1 using regional location, climate and dairy cattle population data.

$$YTE = EF.P.10^{-6} \quad (1)$$

In the equation, EF is the emission factor (kg $head^{-1}$ $year^{-1}$) and was derived according to regional and climate data from tables in the guidelines. In the calculations, the Asian region and warm climatic conditions (average annual temperature 16.3-18.0°C) were taken into account [27]. P is the population of dairy cattle in the Tire area. This was taken as 12.300 head, based on data from 2006 [28].

According to the second approach, in which manure practices which were in use were taken into account, Annual Total Emission values ($ATE_{2nd\ approach}$) (Gg $year^{-1}$), were found by Equation 1 using the specific emission factor (EF_i) for the region where the study was conducted. Values of EF_i were found by means of Equation 2.

$$EF_i = VS_i.365.B_{oi}.0{,}67.\sum_{(jk)} MCF_{jk}.MS_{ij} \quad (2)$$

In Equation 2, index i indicates the animal type category, index j represents the manure management system category, and index k is the climatic system category. Thus, EF_i is the annual emission factor for the type and population of animals (kg); VS_i is the daily amount of volatile solid matter for the type of animals (kg $head^{-1}$ day^{-1}); Bo_i is the maximum methane production capacity for manure per animal (m^3kg^{-1} VS); MCF_{jk} is the methane conversion factor for the various manure management systems in the climatic systems of the research area (%); and MS_{ijk} is the animal fraction in the manure management systems in the climatic system of the research area (%).

The parameters VS, B_o and MS were determined from the relevant tables in accordance with average live weight of dairy cattle in the region, and MCF values from the relevant tables in the IPCC guidelines in accordance with manure management practices and climate conditions.

RESULTS

Characteristics of the Farms

Fig. 1 shows the distribution of the farms according to the characteristics which were examined. Only 4% of farm managers were educated to high school or university level, and 53% of the farms had been established in 1991 or later. The number of animals on 71% of the farms was below 40 animal units. Most of the barns (%89) were of an open or semi-open type. The free system is used in 92% of these barns.

When the location of the animal houses was examined, it was determined that on 63% of farms, animal housing and human habitation were together in the village, while

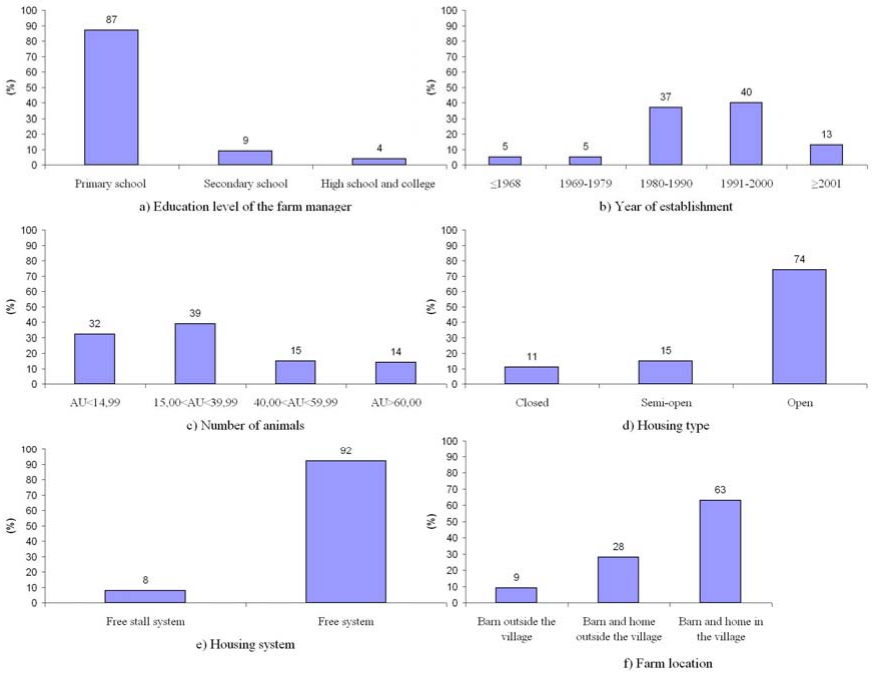

Fig 1. Characteristics of farms

Şekil 1. İşletmelerin özellikleri

on others animal and human housing was together outside the settlement, or human habitation was in the village and animal housing was away from human settlement.

Manure Management Practices in the Research Area

Fig. 2 shows the distribution of the farms according to their manure collection, storage and treatment practices.

On 74% of farms, manure was removed mechanically from the barn *(Fig. 2a)* and in 78%; it was stored piled up on or off the farm *(Fig. 2b)*. On 74% of these farms, the manure was piled up on the farm, and the distance between the dung heap and human dwelling was 25 m on average. On 15% of farms where manure was stored on the farm, it was found that manure was piled on the paddocks and was cleared out once a year. On farms where the manure was stored off the farm, it was determined that it was stored on fields belonging to the farm. On only 6% of farms have a manure pit in use *(Fig. 2b)*. On these farms, the manure pits had a soil floor, were close by the exit of the barn and were open. On farms without a pit, manure was stored on the soil and uncovered.

There were no modern manure management systems on the farms for efficient biomass production and conversion. The manure was used on 99% of the farms as fertilizer for crop-growing. It was determined that on 1% of the farms, the manure was also being used as fuel *(Fig. 2c)*.

Relationships between Farm Characteristics and Manure Management Practices

Table 1 shows the correlation analysis for the relationships between the manure management practices determined on the farms and the farm characteristics.

A significant direct relationship at a level of 1% was found between manure storage method and farm manager's education level, or in other words, a high education level on the part of the farm manager meant the use of a manure pit on large farms. There was a significant relationship at a 5% level between the year of establishment of the farm and the method of manure storage; that is, pits were used on farms that had been established recently. Relationships were found at the 1%

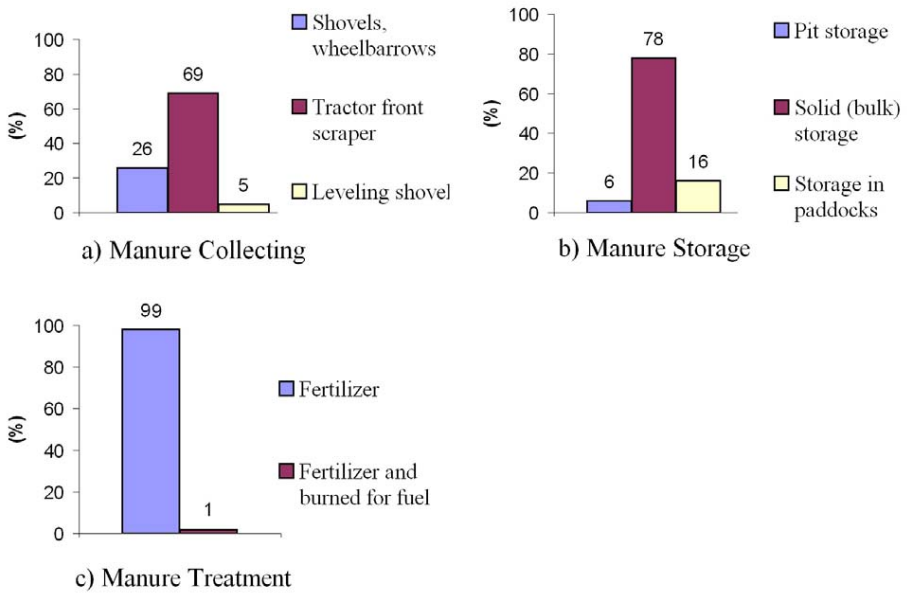

Fig 2. Distribution of farms according to manure management systems

Şekil 2. İşletmelerin gübre yönetim uygulamalarına göre dağılımı

Table 1. *Correlation analysis results related to interactions between manure management practices and farm characteristics*
Tablo 1. *İşletme özelikleri ile gübre yönetim uygulamaları arasındaki ilişkilere ait korelasyon analizi sonuçları*

Farm Characteristics	Manure Management Practices		
	Collection	Storage	Treatment
The Number of Animals	0.403 **	0.299 *	-0.013
Education Level of The Farm Manager	0.079	0.349 **	-0.044
Year of Establishment	-0.015	0.289 *	0.061
Farm Location	-0.067	-0.220	0.088
Housing Type	0.397 **	0.214	0.069
Housing System	-0.122	0.066	0.036

** P<0.01, * P<0.05

level of significance between the size of the farm and the manure collection method, and at 5% with the storage method. A relationship at the level of 1% of significance was found between housing construction type and manure collection method *(Table 1)*.

Emission Values of Methane Gas Arising from Manure Management on the Farms

MCF and MS values used in calculating EF according to the second approach in the IPCC guidelines are given in *Table 2*, and EF and ATE values are given in *Table 3*.

$ATE_{second\ approach}$ and $ATE_{first\ approach}$ were estimated as 0.03 Gg $year^{-1}$ and 0.20 Gg $year^{-1}$ respectively according to the various approaches to emission estimation *(Table 3)*.

Table 4 shows the strengths, weaknesses, opportunities and threats of manure management in the dairy farms in the study area.

Table 2. *MCF and MS values according to manure management systems*
Tablo 2. *İşletmelerin gübre yönetim sistemlerine göre MCF ve MS değerleri*

Manure Management Systems	Population for each of Manure Management System (%)	MCF and MS Values From the IPCC Guide for Temperate Climate and the Region		MCF and MS Values Determinated for the Research Area	
		MCF (%)	MS (%)	MCF_{jk} (%)	MS_{ijk} (%)
Solid Storage	66	1.5	68	0.990	44.88
Pit Storage (Solid)	11	1.5	68	0.165	7.48
Daily Spread	3	0.5	1	0.015	0.03
Pasture/Range/Paddock	19	1.5	13	0.285	2.47
Burned for Fuel	1	10.0	0	0.100	0
Total				**1.555**	**54.86**

Table 3. *EF and ATE values according to emission estimating approaches*
Tablo 3. *Emisyon tahminleme yaklaşımlarına göre EF ve YTE değerleri*

Emission Estimating Approaches	Parameters was Selected from the Related Tables in the Guide		Parameters Determinated for the Research Area		EF (kg $head^{-1}$ $year^{-1}$)	YTE (Gg $year^{-1}$)
Second approach	VS_i (kg $head^{-1}$ day^{-1})	B_{oi} (m^3CH_4 kg VS^{-1})	ΣMCF_{jk} (%)	ΣMS_{ijk} (%)	2.05	0.03
	4.1	0.24	1.555	54.86		
First approach	Emission factor was selected from the related table in the Guide.				16.00	0.20

Table 4. *SWOT analyze results related to manure management practices in the region*
Tablo 4. *Araştırma alanındaki gübre yönetim uygulamalarına ilişkin GZFT analizi sonuçları*

Strengths	Weaknesses
The use of mechanisation is widespread in collecting manure in animal housing Manure is collected frequently from animal housing, so that the housing is clean Pits are used to store manure on larger farms Farm owners are willing to use modern manure management methods Farms are organised in a cooperative	Farms are not large and the education level of farm owners is low. The farms' infrastructure is inadequate for manure disposal Manure produced on the farms is not exploited as a source of income Manure produced on the farms is not used as modern biomass The necessary practices are not followed for the manure to mature Current manure management practices on farms have a detrimental effect on human health and the environment
Opportunities	**Threats**
As the trend to alternative energy sources increases, there will be a related increase in modern manure management practices The fact that cattle farming is widespread gives the necessary potential for modern manure exploitation practices The fact that cattle farms are grouped in an organisation encourages cooperative R&D work with the public and private sectors and with universities Financial support is available from the EU for research projects on developing manure management practices	The small size and the inadequate infrastructure of the farms and the low educational level of the owners has a negative effect on the application of modern management systems The fact that modern manure management systems are not in use on small farms prevents appropriate exploitation of the manure

DISCUSSION

Manure Management on the Farms

Compared with dairy farms in other parts of Turkey, the farms in the region under study are on a larger scale and are better in terms of the housing of the animals [29-34]. However, it was found that the manure management and infrastructure of dairy cattle farms in the Tire area is insufficient and does not conform to the relevant technical standards and regulations. Manure is not made use of efficiently in the area, and it constitutes a significant problem for human health and environmental pollution. Animal housing was closer to human dwellings than the distance recommended by the Minimum Distance Curve of the Ministry of the Environment and Forests (225 m for a farm with 100 animal units) [35]. Distance between the dung heap and human dwelling was determined to be inadequate for proper hygiene [7]. On only 6% of farms have a manure pit in use and these pits had been constructed without taking into account such factors as capacity, distance from human dwellings, prevailing wind direction or rainfall, which are specified in the standards [7,35]. On farms without a pit, manure was stored on the soil and uncovered and this method leads to unwanted results such as seepage of the runoff into the soil, disease, smell and flies. These problems are made worse by rainy weather. This can have a negative effect on the health of humans and animals, and on the hygiene of the surrounding area. The necessary procedures were not being followed to turn this manure into fertilizer that would be beneficial on the fields [36]. In the Tire area as in other parts of Turkey, manure management practices and the lack of infrastructure are causing severe problems, and insufficient use is being made of the manure [30,31,34,37,38].

Farms in the area are small and scattered, making the use of modern management systems difficult. On the other hand, it was seen that farm owners who were members of cooperatives were inclined towards the application of modern manure management systems.

Statistical analyzes show that, in closed barns on small farms, generally no use was made of mechanization for manure collection. No statistical significant relationship was found between manure treatment system and any of the characteristics of the farms under study in the research area.

Methane Emissions and Improvement of Manure Management in the Region

$ATE_{second\ approach}$ and $ATE_{first\ approach}$ were estimated as 0.03 Gg.year^{-1} and 0.20 Gg.year^{-1} respectively according to the various approaches of IPCC to emission estimation. Although the climate and population data used in the two approaches was the same, the use of individual emission factors calculated for the existing manure management practices in the study area in the second approach caused methane gas emissions to come out lower in this approach. EF values in the first approach were taken as 16 kg.head^{-1}.year^{-1}. This value was determined for dairy cattle in a warm climatic zone in the Asian area of the IPCC guidelines, and is an average value taking in a wide area and a large population.

As specified in IPCC Guide, when manure is stored or treated as a liquid (e.g., in lagoons, ponds, tanks, or pits), it tends to decompose anaerobically and produce a significant quantity of methane. When manure is handled as a solid (e.g., in stacks or pits) or when it is deposited on pastures and rangelands, it tends to decompose aerobically and little or no methane is produced. In the Guidelines, it is accepted that about half of cattle manure is used as fuel in the Asian area, and the rest is used in dry systems [16]. However, it was found that in the study area, only 1% of cattle manure was being burned and 99% of manure was handling as other manure management practices (solid storage, pit storage (solid), daily spread, pasture/range/paddock). For this reason, the emission value calculated according to the second approach, in which the population is taken into account, is seen to be lower than the value calculated by the first approach regarding manure management practices in the research area. This can be said to derive from the use of solid systems in the area which do not cause high emissions, and from the fact that manure is used less as a fuel than in the Asian region.

However, the low estimated emission value do not shows that the current manure management systems are good for human and animal health and hygiene.

In the same way, in studies by Gonzalez and Ruiz [39] in Mexican conditions, by Gupta et al.[40] in India and Gac et al.[41] in France, the emission factor for cattle according to the values recommended by the IPCC guidelines was considerably higher than the individual emission factor values determined for the study areas. This was said to arise from the values predicted in the first approach being determined according to manure management practices generalized for very wide areas.

The results of SWOT analysis show that the small capacity of the farms in the region, the insufficiency of the infrastructure and the low education level of the farm owners hinder successful manure management, but that the current organization into cooperatives can contribute to developing and spreading modern manure management practices.

In order to provide for an environmentally sensitive and successful manure management system in the dairy farms of the area which is not detrimental to human and animal health, there is a need for animal housing systems which enable mechanization and which conform to technical standards and legal provisions, and for manure pits

which are well-designed and do not leak. In addition, the establishment of large-capacity biogas plants to produce bioenergy and organic fertilizer would contribute to a reduction in greenhouse gases. In order to arrive at a truer estimate of Turkey's methane gas emission from manure management, it is necessary to take into account current manure management practices and the breeds of animal used, and to determine the area's particular emission factors according to the second approach of the IPCC.

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