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The Effect on Organic Agriculture of Insulation of Rural Houses in Turkey

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Abstract: This present study investigated how much energy and dung savings can be obtained with the insulation of rural houses. Energy savings and dung savings are calculated based on degree-days, fuel types and thermal resistance of walls. The results showed that by enveloping a rural house with proper insulation thickness, energy savings differ between 20 and 86% and payback periods differ between 0.52 and 4.64 years based on degree-days, fuel types and thermal resistance of walls. When rural houses are optimally insulated, the dung savings are calculated as 3970 kton. In return, these savings can directly be used in organic farming. Therefore, insulation of rural houses is crucial for energy savings.

Key words: Organic agriculture, energy savings, insulation, rural house

INTRODUCTION

Turkey is situated at the meeting point of three continents (Asia, Europe and Africa). Its area is 779,452 Sq. km. Human settlements are generally divided into rural and urban. In rural areas, agricultural production dominates the life style, whereas in urban settlements industrial production plays an important role. According to the 2007 census, the total population of Turkey is about 70 millions and 586 thousands. It was noted that 30% of the population resided in rural areas.

Energy consumption is rapidly increasing due to the population increase. Turkey's energy consumption has increased by an average of 4.4% each year over the past years (Demirbas, 2001). Residential energy requirements vary from region to region depending on climate, dwelling type and level of development (Hasan, 1999). The production and consumption of primary energy sources used in rural houses of Turkey is given in Table 1. Traditional fuels predominate in rural areas. As shown in Table 2, fuelwood and animal wastes are the major energy sources in the households in rural areas. Almost all biomass energy is consumed for heating, cleaning and cooking needs of rural people (Türker and Kaygusuz, 2001). Fuelwood, animal wastes, agricultural crop residues and logging wastes have been used many years for direct burning in Turkey. These sources are often called non-commercial energy sources, but in Turkey, fuelwood has a trade market since it is the primary fuel in the poor rural and urban districts (Kaygusuz, 1997). Using animal dung and wood as a primary heat source is the least efficient way of using this biomass energy source. A more efficient way of energy conversion may be achieved if animal waste is converted into biogas and the residue, after this process, is used for as fertilizer to condition soil in organic farming (Gökmen *et al*., 2004).

Organic farming differs from integrated or conventional systems by its defined set of production standards. These standards are implemented in the form of nationally adapted organic farming regulations in most countries (Michelsen, 2002). Organic farmers do not use synthetic fertilizers and pesticides and attempt to close nutrient cycle on their farms, protect environmental quality and

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Table 1: Coal, fuelwood and dung production and consumption in ktoe and kton for 2003 in Turkey

	ktoe		kton	
Fuel	Production	Consumption	Production	Consumption
Coal	1083	11283	2011	17765
Fuelwood	4497	4497	14991	14991
Dung	1251	1251	5439	5439

Table 2: Percentage proportions of energies within the general energy sources for 1999 in Turkey

Final energy consumption		Sectoral energy consumption		Consumption in household	
Resource	Proportion (%)	Sector	Proportion (%)	Resource	Proportion (%)
Petroleum and gas	55.6	Household	23.9	Petroleum and gas	28.2
Solid fuels	29.1	Industry	27.4	Solid fuels	18.8
Fuelwood	7.2	Transport	17.4	Fuelwood	30.6
Animal wastes	1.2	Agricultural	3.8	Animal wastes	15.4
Agricultural wastes	1.0	Non-energy	27.5	Agricultural wastes	1.2
Electricity	5.9	Total	100.0	Electricity	5.8
Total	100.0			Total	100.0

enhance beneficial biological interactions and processes (Vandermer, 1995). Under organic management, traditional conservation-minded farming methods are combined with modern farming techniques, but conventional inputs such as synthetic pesticides and fertilizers are excluded. Instead of synthetic inputs, compost, animal and green dung are used to build up soil fertility; pests are controlled naturally, crops are rotated; and both crops and livestock are diversified (Reganold *et al*., 2001).

Agriculture has traditionally used animal dung for fertilizer and improving soil physical and chemical properties and using the nutrients for growing crops. Energy production from animal dung, crop residues and/or other organic wastes has been utilized in agriculture with varying degrees in different parts of the world (Westerman and Bicudo, 2005). Besides its use of energy source, animal dung also supplies valuable organic matter. The large quantities of slurry and dung produced annually in many areas in which cattle are raised could be an important resource for organic matter and nutrients. Recycling these wastes via land application could lead to improvements in physical properties of soil, such as soil porosity, structure and water holding capacity (León-González *et al*., 2000; Ouédraogo *et al*., 2001; Nyamangara *et al*., 2001). Organic matter improves soil tilt, increases water holding capacity, lessens erosion, improves soil aeration and has a beneficial effect on soil microorganisms and plants.

Organic agriculture in Turkey started with the international demand from major export partners. Organic agriculture was initiated in Izmir which is located in the Aegean region in 1985. Today, organic agricultural production has expanded to all regions in Turkey. The number of farmers in Turkey applying with organic agricultural methods is also increasing year by year. Turkey is a major producer and exporter of various agricultural products. Production has been shaped according to the standards and certification systems of the importing countries, which were mainly EU countries. Currently, 103'190 ha are managed organically, which corresponds to 0.4% of the total agricultural area.

As mentioned before, various traditional energy sources are used in rural houses in Turkey. For heating, dung is mostly consumed in villages except in those close to the forest regions. The dung which should be used at the organic agriculture is used for space heating in the rural houses. This is a serious loss of fertilizer for the land to be cultivated (Gökmen *et al*., 2004). If rural houses were insulated, heat loses would decrease an important amount.

Turkish government has issued a new regulation in 2000, called the rules of heat insulation in buildings for setting certain standards for insulating buildings according to four climate regions. The fourth region has the most severe winter condition, where a large amount of energy is used for heating in rural houses. The range of the heating degree-days varies significantly from one region to another.

For example, the annual heating degree-days for Iskenderun (located in the east Mediterranean) is 878, while it is 5443 for Ardahan (located in the northeast of Turkey) (Bolattürk, 2006). This means that a building in Ardahan requires 6.2 times more heating energy than the same building located in Iskenderun. Also, in this study calculations have been made according to mean degree-days of Turkey.

Jaber (2002) mentioned that space heating load can be reduced by about 50% when economically-viable insulating measures are applied to the building envelopes, i.e., to ceilings and walls. Mohsen and Akash (2001) researched the energy saving measures in building insulations for different materials. They found that energy savings could be reached up to 77% when polystyrene is used for both wall and roof insulation. Al-Sanea *et al*. (2005) investigated effect of average electricity tariff on the optimum insulation thickness in building walls by using a dynamic heat-transfer model and an economic model based on the present-worth method. Hasan (1999) found that savings up to 21 $ m^{-2} of wall area are possible for rock wool and polystyrene insulation, using life-cycle cost analysis to compute optimum insulation thicknesses. He determined payback periods as 1-1.7 years for rock wool insulation and 1.3-2.3 years for polystyrene insulation, depending on the type of wall structure. Comakli and Yuksel (2003) showed that the saving may be as much as 12.13 $ m^{-2} of wall area depending on the optimum insulation thicknesses for the coldest cities of Turkey over a lifetime of 10 years. Bolattürk (2006) calculated the optimum insulation thicknesses, energy savings and payback periods for 16 cities from four climate zones of Turkey. He determined 0.02 to 0.17 m optimum insulation thicknesses, 22 to 79% energy savings and 1.3 to 4.5 years payback periods depending on the city and fuel type.

This study investigated the effect of organic agriculture growing of insulated rural houses in Turkey. For different external wall construction, the optimum insulation thicknesses, using life-cycle cost analysis over the lifetime of 10 years, are determined according to the highest, lowest and mean degree-days in Turkey. Also, the amount of energy saved and the payback periods for various degree-days and different wall types are calculated. In rural houses at current situation, the most suitable fuel for heating is coal replace dung and fuelwood.

MATERIALS AND METHODS

Optimum Insulation Thickness and Heat Losses at the External Walls

House materials used in rural settlements differ according to the location and climate of the area. The external wall materials can be stone, adobe (mud bricks), brick, or wood. The walls of new houses are constructed with hollow concrete blocks. Construction systems of rural houses in Turkey can be divided into three types: masonry, framed and composite structures. Masonry structures are built with stone, adobe, brick and blocks. In rural areas of the country 58% of these masonry structures are of stone, 32% are of adobe, 7% are of brick and 3% are of other masonry units such as concrete block and aerated concrete (Dikmen and Elias-Ozkan, 2004). Various wall structures commonly used in rural houses and their thermal characteristics are given in Table 3.

Heat losses from a building are computed through losses in the walls, floor, ceiling and air infiltration. In this study, only external wall losses will be considered in the insulation thickness optimization. Values are calculated by the following equations.

The annual heat loss per unit area is:

$$E_a = \frac{86400DD}{(R_t + \frac{x}{k})\eta} \tag{1}$$

where, DD, R_t, x, k and η are the degree-days, the total wall thermal resistance excluding the insulation layer resistance, insulation thickness, thermal conductivity of the insulation material and efficiency of the heating system, respectively (Hasan, 1999).

Table 3: Wall structure and thermal characteristics

Wall structure	Thickness (m)	Thermal conductivity (W/mK)	Conductance U (W/m² K)	Resistance (m² K/W)
Wall 1			2.78	0.360
Stone	0.50	3		
Int. Plaster	0.02	0.87		
Wall 2			1.69	0.590
Ext. plaster	0.03	1.40		
Adobe	0.30	0.80		
Int. Plaster	0.02	0.87		
Wall 3			1.63	0.615
Ext. plaster	0.03	1.40		
Brick	0.20	0.50		
Int. Plaster	0.02	0.87		
Wall 4			1.17	0.856
Ext. plaster	0.03	1.40		
Hollow block	0.20	0.31		
Int. Plaster	0.02	0.87		

Then the annual fuel consumption is:

$$m_a = \frac{86400DD}{(R_t + \frac{x}{k})\eta} \tag{2}$$

where, H_u is the lover heating value of the fuel given.

The total cost of heating the insulated building in present dollars is given by:

$$C_t = \frac{86400DD}{(R_t + \frac{x}{k})H_u\eta} C_f PWF + C_{in} \tag{3}$$

where, C_f, PWF and C_{in} are fuel cost in \$ kg^{-1}, present worth factor and insulation cost in \$ m^{-3}, respectively.

The optimum insulation thickness is obtained by minimizing the total heating cost C_t. Hence the derivative of C_t with respect to x is taken and set equal to zero, from which the optimum insulation thickness x_o is obtained as follows:

$$x_o = 293.94\left(\frac{DDkC_f PWF}{H_u C_i \eta}\right)^{1/2} - kR_t \tag{4}$$

RESULTS

It is an important disadvantage that the dung which should be used at the organic agriculture is used for space heating in the rural houses. As shown in Table 2, dung with a 15.4% proportion is considered as a major energy source. Dried dung making in rural areas of developing countries is usually performed by women with the assistance of children. Women made dried dung can be seen clearly in many rural regions of Turkey. Women have less time for their other daily duties, such as cooking, washing and child rearing, which may affect the nutrition and health of the entire family (Türker and Kaygusuz, 2001).

Dung is mostly consumed for heating in villages. The external walls in rural houses are not insulated and this makes the energy saving more vital in rural houses. The heating load decreases with increasing insulation thickness. Minimum total cost is taken for the insulation thickness. For wall 1, which is commonly used in rural houses in Turkey, the annual heating cost is calculated according to

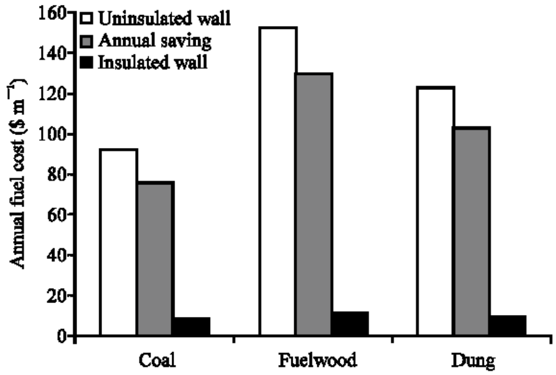

Fig. 1: Annual savings, insulated and uninsulated heating cost for stone wall versus various fuel types at 878 degree-days

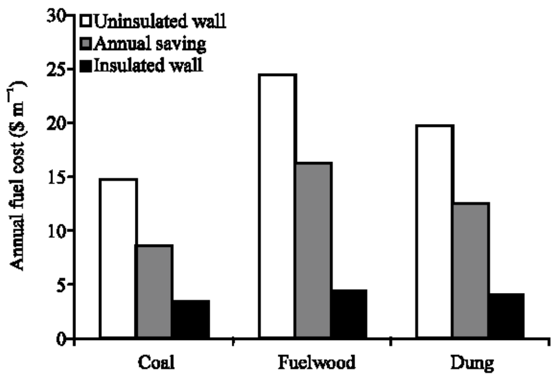

Fig. 2: Annual savings, insulated and uninsulated heating cost for stone wall versus various fuel types at 5443 degree-days

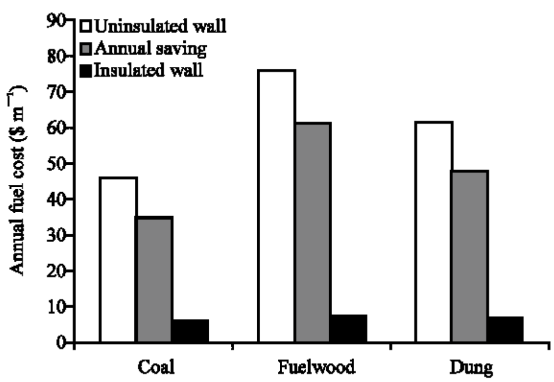

Fig. 3: Annual savings, insulated and uninsulated heating cost for stone wall versus various fuel types at 2735 degree-days

various fuel types for insulated and uninsulated external wall (Table 4). As shown in Fig. 1-3, for insulated wall 1, annual energy saving for dung at minimum, maximum and the mean of degree-days

Table 4: The parameters used in the calculations

Parameters	Value
Coal	
Fuel price	0.199 $ kg^{-1}
Heating value	31.35×10^6 J kg^{-1}
System efficiency	0.65
Fuelwood	
Fuel price	0.135 $ kg^{-1}
Heating value	12.0×10^6 J kg^{-1}
System efficiency	0.65
Dung	
Fuel price	0.080 $ kg^{-1}
Heating value	9.6×10^6 J kg^{-1}
System efficiency	0.60
Interest rate (%)	17.7
Inflation (%)	9
Lifetime (N)	10 years
Insulation expand polistren	
Conductivity (k)	0.03 W mK^{-1}
Cost	75 $ m^{-3}
Density	22 kg m^{-3}

Table 5: Optimum insulation thickness, energy savings and payback periods for analyzed maximum, minimum and mean of Turkey degree-days and various wall structures

		Coal				Fuelwood			
DD	Wall structure	Optimum insulation thickness (m)	Annual energy saving ($ m^{-3})	Energy savings (%)	Payback period (years)	Optimum insulaiton thickness (m)	Annual energy saving ($ m^{-3})	Energy savings (%)	Payback period (years)
5443	1	0.104	75.3	0.82	0.67	0.137	130.6	0.86	0.52
	2	0.097	40.1	0.72	1.12	0.130	71.9	0.78	0.86
	3	0.096	37.9	0.71	1.17	0.129	68.2	0.77	0.90
	4	0.089	23.1	0.60	1.67	0.122	43.3	0.68	1.28
878	1	0.035	8.7	0.59	1.74	0.049	16.4	0.67	1.33
	2	0.028	3.4	0.38	2.99	0.042	7.4	0.49	2.26
	3	0.028	3.1	0.36	3.14	0.041	6.8	0.48	2.37
	4	0.020	1.2	0.20	4.64	0.034	3.3	0.32	3.45
2735	1	0.071	34.7	0.75	0.96	0.094	61.5	0.81	0.74
	2	0.064	17.2	0.61	1.61	0.087	32.2	0.69	1.23
	3	0.063	16.2	0.60	1.68	0.086	30.4	0.68	1.29
	4	0.056	9.0	0.47	2.42	0.079	18.2	0.57	1.84

		Dried dung			
DD	Wall structure	Optimum insulaiton thickness (m)	Annual energy saving ($ m^{-1})	Energy savings (%)	Payback period (years)
5443	1	0.122	103.0	0.84	0.581
	2	0.115	55.9	0.75	0.967
	3	0.114	52.9	0.74	1.009
	4	0.107	33.1	0.65	1.435
878	1	0.042	12.5	0.64	1.499
	2	0.036	5.4	0.45	2.555
	3	0.035	4.9	0.43	2.675
	4	0.027	2.2	0.27	3.918
2735	1	0.083	48.0	0.78	0.828
	2	0.076	24.6	0.66	1.386
	3	0.075	23.2	0.65	1.448
	4	0.068	13.5	0.53	2.074

in Turkey, are 12.5, 103 and 48.0 $ m^{-2}, respectively. Calculations for other wall structures are given in Table 5 as well.

The lifetime energy savings for four different walls are shown in Table 5. Energy savings vary between 20 and 86% depending on degree-days, wall structure and fuel type. Payback periods of the insulation are shown in Table 5 for various wall types and degree-days. Payback periods of the insulation vary between 0.52 and 4.64 years depending on degree-days, fuel and wall types.

CONCLUSION

From the analysis, the following conclusion can be drawn:

- Energy savings vary from 20 to 86% depending on degree-days, fuel types and thermal resistance of walls. Energy savings of coal, fuelwood and dung vary between 20-82% and 32-86% and 27-84%, respectively. In optimally insulated rural houses, energy savings is fairly high. These values show that insulation of rural houses is very important
- Payback periods vary from 0.52 to 4.64 years depending on degree-days, fuel types and wall types (Table 5). Payback periods of coal, fuelwood and dung vary between 0.67-4.64 and 0.52-3.45 and 0.58-3.92, respectively
- In the rural areas of Turkey, a huge quantity of sun dried animal dung is used for heating purposes. This use often brings a major concern that farmers use synthetic fertilizer which eventually causes ecological problems. In insulated rural houses, amount of animal waste use decreases for heating purposes. Accordingly, utilizing animal waste in organic agriculture is much more useful than that of in heating purposes. Annual dung consumption for heating is 5439 kton in Turkey. If rural houses were insulated, the dung saving would be 3970 kton. These savings can directly be used in organic farming

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