Adaptation and mitigation strategies for dairy cattle: Myths and realities in Indian condition - A review

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Received: 07-11-2014 Accepted: 06-12-2014 DOI: 10.18805/ag.v36i4.6665

ABSTRACT

The anticipated climate change will adversely affect the productivity of livestock directly due to increased heat stress, indirectly it will affect the livestock by causing feed and fodder shortages, reducing biodiversity, water availability and increasing the incidences of vector-borne livestock diseases. On the other hand, the livestock keeping farm households mainly small farm households will be affected directly as they rear livestock for their livelihood. Interestingly, over the years, the livestock keeping households have increased at a tremendous rate for the small and marginal, medium and semi-medium farm household categories as they reduce the risk arising from extreme climate conditions. So, it becomes imperative to adopt adaptation and mitigation strategies to reduce the impact of climate change on livestock given their importance in smallholder farmers’ livelihood in India. Some of researchers in past have recommended certain adaptation and mitigation strategies for reducing the climate change impact on livestock. But, are these adaptation and mitigation strategies applicable or viable in the context of smallholder farmers in India? This remains an unsolved puzzle. This paper tries to demystify certain myths associated with these strategies as well as explore the ground realities. The present policy of indiscriminate crossbreeding of local cattle with exotic cattle should be reviewed and reoriented for smallholder dairy farmer especially, in dry and rainfed regions where there is scarcity of fodder and water which are required heavily by crossbred cattle. The study clearly reflects that the adaptation research should be country specific as the strategies suitable for one country may not be viable for the others as there is considerable difference in local conditions of different countries.

Key words: Adaptation, Climate change, Dairy cattle, Mitigation, Smallholder farmers.

Milk production is an important activity of Indian agriculture in the Indian economy and socio-economic development. Dairying is the backbone of the marginal farmers and landless labourers spread over about 6 lakh villages scattered throughout the country. About 5.50 per cent of total working population of India is engaged in animal husbandry sector (Sharma and Tiwari, 2011). The sector provides large self-employment to millions of households in rural areas, employed about 11.44 million in as a principal status and 11.01 million in subsidiary status, which does not include persons employed in sale, re-processing and transport of animal products at secondary market level. The landless, marginal and small farmers hold about 82 per cent of dairy animals and contribute about 70 per cent of milk production in India.

Around 20 per cent of the milk produced in India is from the organised sector and 80 per cent is from the unorganized milk producers. The following table gives a clear picture of rural life as well as resource poverty of smallholders. From the Table-1 it is clear that though the total operated area under small holders has increased, the number of holdings have also increased due to further fragmentation of inherited land. Alternative options is to keep livestock for their livelihood as it reduces the risk arising from extreme climate conditions like floods, droughts, rising temperature etc. Interestingly, livestock such as cattle, buffalo, sheep and goat per holding have increased at a tremendous rate for the small and marginal, medium and semi-medium farm household categories.

It is estimated that approximately 20 to 30 per cent of plant and animal species assessed so far are likely to be at increased risk of extinction if increases in global average temperature exceed 1.5 to 2.5°C (IPCC, 2007). In India, climate change is believed to reduce milk production by 1.6 MT & 15 MT in 2020 & 2050 respectively (Upadhyay et al., 2008). Due to climate change, developing countries may lose 25 per cent of animal production (Thornton, 2010).

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The climate change will adversely affect the livestock directly as well as indirectly. Directly, due to increased heat stress, physiological (rectal temperature, respiration rate, dry matter intake etc.) as well as production functions (milk production, meat production) will be impaired (Davison et al., 1996). Indirectly, climate change will affect the livestock by reduced water availability, feed and fodder shortages, reducing biodiversity and increasing the incidences of vector-borne livestock diseases (Thornton et al., 2007).

So, it becomes imperative to adopt adaptation and mitigation strategies to reduce the impact of climate change on livestock given their importance in smallholder farmers’ livelihood in India. Some of researchers in past have recommended certain adaptation and mitigation strategies for reducing the climate change impact on livestock. But, are these adaptation and mitigation strategies applicable or viable in the context of smallholder farmers in India? This remains an unsolved puzzle. This paper tries to demystify certain myths associated with these strategies as well as explore the ground realities.

**Shelter modification:** Shades are the simplest method to reduce the impact of high solar radiation. Most of the researchers have focused on providing artificial shade to cattle for reducing the heat stress and improving their productivity. These researchers who mostly belong to developed countries call for building complex housing structures for providing shade as well as ventilation. Major design parameters for artificial shade structures include: 1) orientation, 2) floor space, 3) height, 4) ventilation, 5) roof construction, 6) feeding and water facilities, and 7) waste management system (Bucklin et al., 1991; Bibbiani and Consorti, 2005). Blocking effects of heat stress through the use of properly constructed shade structures alone increased milk production by 10-19 per cent in studies conducted in Florida (Bucklin et al., 1988). In a study performed in the central milk supply area of Santa Fe (Argentina) it was found that protected animals presented lower afternoon rectal temperature and respiration rate, and yielded more milk and protein. Air moving is an important factor in the relief of heat stress, since it affects convective and, according to air humidity, evaporative heat losses. Forced ventilation, provided by fans and coolers, is a very effective method, if properly designed. An effective way of cooling cattle is spray evaporative cooling. There are several methods available: mist, fog and sprinkling systems. These systems use high pressure, fine mist, and large volumes of air to evaporate moisture and cool the air surrounding the cow. A study in Louisiana showed cooling benefits from air movement and wetting the cow’s body surface. They reported that sprinkling cows before entering a shade reduced respiration rate by 65 to 81 per cent and body temperatures by 46 to 50 per cent over shade alone. They concluded that using sprinklers in combination with supplemental airflow was superior to a fan alone or sprinkling.

These measures for shade require huge investments which are beyond the thinking of resource-poor smallholder farmers in India. These measures have been found appropriate for large herd size commercial dairy farms which form the bulk of dairy farms in developed countries but in India 70 per cent milk is produced by marginal, small and landless farmers.

### TABLE 1: Category/Size-wise Distribution of Operational Land Holdings in India

<table>
<thead>
<tr>
<th>Category of Land</th>
<th>Year</th>
<th>Marginal (below 1.00 Ha.)</th>
<th>Small (1.00 to 1.99 Ha.)</th>
<th>Semi-medium (2.00 to 3.99 Ha.)</th>
<th>Medium (4.00 to 9.99 Ha.)</th>
<th>Large (10.00 Ha. &amp; above)</th>
<th>All Size Classes</th>
</tr>
</thead>
<tbody>
<tr>
<td>Distribution of Livestock (%)</td>
<td>2001-02</td>
<td>46.50</td>
<td>22.50</td>
<td>17.50</td>
<td>10.60</td>
<td>2.90</td>
<td>100.00</td>
</tr>
<tr>
<td>Annual growth (in %)</td>
<td>1991-92</td>
<td>36.90</td>
<td>23.50</td>
<td>20.20</td>
<td>14.70</td>
<td>4.80</td>
<td>100.00</td>
</tr>
<tr>
<td>Number of Holdings ('000)</td>
<td>2001-02</td>
<td>65285.85</td>
<td>21498.80</td>
<td>13349.71</td>
<td>6374.39</td>
<td>1197.71</td>
<td>107706.00</td>
</tr>
<tr>
<td>Annual growth (in %)</td>
<td>1991-92</td>
<td>56610.00</td>
<td>20103.00</td>
<td>13589.00</td>
<td>7217.00</td>
<td>1543.00</td>
<td>99062.00</td>
</tr>
<tr>
<td>Operated Area ('000 ha.)</td>
<td>2001-02</td>
<td>27380.47</td>
<td>30503.72</td>
<td>36242.07</td>
<td>36617.62</td>
<td>18649.03</td>
<td>149393.00</td>
</tr>
<tr>
<td>Annual growth (in %)</td>
<td>1991-92</td>
<td>24071.00</td>
<td>28540.00</td>
<td>37187.00</td>
<td>42684.00</td>
<td>25077.00</td>
<td>157559.00</td>
</tr>
</tbody>
</table>

Source: Department of Animal Husbandry Dairying and Fisheries, National Sample Survey Organisation and Ministry of Agriculture, Govt, 2001-02
Wallowing ponds can also be an alternative for buffaloes and application for 15-20 minutes before milking in buffaloes smallholder farmers in India. Therefore, some alternatives method for alleviating heat stress for resource-poor in some developing countries cannot be a cost-effective which has proved to be useful to relief dairy cows heat stress sprinkling and fan system, for 30 minutes before milking. The measures suggested above may not go down well in context of smallholder dairy farmers in India due to following reasons. Firstly, in India, the smallholder dairy farmers graze as well as stall feed their animals. But the above measures suggested hold true exclusively for stall fed animals. For instance, the deficit of potassium and magnesium is not common in case of grazing livestock. Secondly, the smallholder farmer is ignorant as well as poor. So, even if he knows about recommended feeding practices he will not be able to adopt them due to the poor resource endowment.

For shades, it is appropriate that the smallholder should use natural shade. Trees are an excellent source of shade and if given the choice cows will generally seek the protection of trees rather than man-made structures (Shearer, 1999). They are not only effective blockers of solar radiation but the evaporation of moisture from leaf surfaces cools the surrounding air without appreciably interfering with air circulation. Also, an animal acquires very little radiant heat load from the shade of a tree compared with a metal roof. Consequently, trees are a highly desirable natural resource in the environment of the dairy cow. Furthermore, in large herds, trees have a short life span. As cows congregate to seek protection from the summer sun they quickly develop mud holes at the base of the tree. This soon leads to death of the tree and loss of this natural shade source. This is reason why natural shade with all its advantages has not been used in developed countries to overcome the heat stress. So, natural shade which involves no cost is relevant for Indian smallholder dairy farmers not the complex housing system suggested by researchers from developed countries. For housing the animals in India, straw thatched sheds or tall, simple, asbestos shades with reflective white outside and absorptive black under-surface of roof are appropriate and cost-effective.

The air speed is also crucial for livestock production. The optimum air speed should be 4-5 mph for optimum performance of the cattle. This air speed is available in natural environment in India. So, there is no need for smallholder farmers to go for expensive fans and coolers which is a hard proposition to go for. Also, misters, foggers and sprinkling systems as suggested by researchers are also very proactive measures which are beyond the reach of smallholder farmers. Further, some researchers have questioned the use of evaporative cooling systems in climates with high relative humidity because when relative humidity increases above 70 per cent, the potential reduction in Temperature humidity Index (THI) is less than 10 per cent (Collier et al., 2006). Approximately 47 per cent of the total area of the country i.e. 153.78 million hectares has been classified as either sub-humid or humid. So, these measures of cooling the cattle are not viable in most parts of India. Even, the single use of a sprinkling and fan system, for 30 minutes before milking which has proved to be useful to relief dairy cows heat stress in some developing countries cannot be a cost-effective method for alleviating heat stress for resource-poor smallholder farmers in India. Therefore, some alternatives for smallholder farmers are suggested. For example, water application for 15-20 minutes before milking in buffaloes increases the milk yield (Verma and Hussain, 1988). Wallowing ponds can also be an alternative for buffaloes and cattle to alleviate stress. Smallholder farmers can construct village ponds for their cattle and buffalo. The cooling ponds can lower the cows’ temperature by 1-2°F depending on the time of day they entered the cooling ponds (Bray, 2000). Using a cooling pond on a farm may benefit both animal welfare and production for areas where heat stress is a problem without compromising milk quality. The use of ponds call for an effective maintenance and management on the part of dairy farmers otherwise dirty ponds can lead to diseases like mastitis. At least once a year, usually during the winter, the pond should be fenced and the water removed by pumping. The government should make required investments in construction and maintenance of the village ponds and these investments should be channeled through village Panchayats. Economic incentives should be provided to the villages who maintain their ponds in a better way as is done in “Total Sanitation Campaign” with introduction of Nirmal Puraskar.

**Nutritional management:** The next adaptation and mitigation strategy which has been proposed by certain researchers is nutritional management. Some of these researchers are: West, 1995; Linn, 1997 etc. Again certain myths are associated with nutritional management as adaptation and mitigation strategy which are tried to be countered in this section. Nutritional management involves various aspects, some of which are discussed here under as following:-

**Ration adjustments:** As the dry matter intake is decreased in heat stressed dairy cattle, so the goal of ration adjustments is to adjust rations to increase energy and protein intake while maintaining rumen and cow health. Some of the measures are as follows:

Balancing ration protein levels to minimize high levels of soluble and rumen degradable protein; adding buffers (sodium bicarbonate, magnesium oxide, and sodium sesquicarbonate) to help in maintaining a normal rumen environment; increasing ration magnesium and potassium levels to counteract the higher potassium and magnesium losses in heat-stressed cows; adding yeast or yeast cultures to the ration etc.

The measures suggested above may not go down well in context of smallholder dairy farmers in India due to following reasons. Firstly, in India, the smallholder dairy farmers graze as well as stall feed their animals. But the above measures suggested hold true exclusively for stall fed animals. For instance, the deficit of potassium and magnesium is not common in case of grazing livestock. Secondly, the smallholder farmer is ignorant as well as poor. So, even if he knows about recommended feeding practices he will not be able to adopt them due to the poor resource endowment.
Therefore, it is the responsibility of extension agencies to educate the farmers about the climate change and corresponding ration adjustments. Also, the government should supply mineral mixture free of cost or at very cheap rates so as to provide different buffers in the diet and to avoid mineral imbalances.

Feeding management: The feeding management practices used also offer opportunities for alteration in trying to minimize the effects of heat stress. Some of the key considerations in this area are: fresh, palatable, high quality feed should be in the feed mangers at all times to provide maximum opportunity for feed consumption. If the feed in the mangers is warm, musty or spoiled, it needs to be removed and discarded; the feed should be pushed up frequently; the cows should be able to reach the feed; rations should be mixed and delivered uniformly on a daily basis; all cows should be able to eat at the feed manger at the same time; if the cows are sorting the ration and leaving the coarse particles then some added water or molasses may help the feed stick together better. Again, these feeding management practices are suitable for stall-fed and large size commercial herds and are unsuitable for poor small holder farmers following both grazing as well as stall fed method of feeding. Secondly, there is acute shortage of feed and fodder resources in India. The cattle and buffaloes are normally fed on the fodder available from cultivated areas, supplemented to a small extent by harvested grasses and top feeds. The three major sources of fodder supply are crop residues, cultivated fodder and fodder from common property resources like forests, permanent pastures and grazing lands.

The country faces a net deficit of 63 per cent green fodder, 24 per cent dry crop residues and 64 per cent concentrates (Table-2). Supply and demand scenario of forage and roughage is presented in Table 2. The situation is further aggravated due to increasing growth of livestock particularly that of genetically upgraded animals. The available forages are poor in quality, being deficient in available energy, protein and minerals. To compensate for the low productivity of the livestock, farmers maintain a large herd of animals, which adds to the pressure on land and fodder resources. Due to ever-increasing population pressure of human beings, arable land is mainly used for food and cash crops, thus there is little chance of having good-quality arable land available for fodder production, unless milk production becomes remunerative to the farmer as compared to other crops. To meet the current level of livestock production and its annual growth in population, the deficit in all components of fodder, dry crop residues and feed has to be met from either increasing productivity, utilizing untapped feed resources, increasing land area (not possible due to human pressure for food crops) or through imports.

Source: Planning Commission, GOI, 2002. Figures in parentheses indicate the quantities in Million MT. Another problem is that the land available as permanent pastures and grazing land is declining while the population of cattle and buffalo is growing (Table-3). The scene in case of permanent pasture and grazing land is also very much disturbing. The following tables give a clear picture of permanent pastures & grazing land and fodder situation in India.

So, it is clear that there will be reduced availability of feed and fodder i.e. the supply and demand gap of feed and fodder will be widened and also there will be increased pressure on existing pastures land. Therefore, it will not be possible for farmer to arrange for fresh fodder at all times. So, it is important that the farmers should be incentivized to grow fodder crops on a part of their small and marginal landholdings. The government should provide good quality seeds of green fodder and dry fodder crop. Also, the farmer should be made aware of methods of storage of greens like hay-making, silage making etc. It has been reported that increased temperatures increase lignifications of plant tissues and therefore reduce the digestibility and the rates of

<table>
<thead>
<tr>
<th>Year</th>
<th>Supply (in Million MT)</th>
<th>Demand (in Million MT)</th>
<th>Deficit as % of demand (actual demands)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Green</td>
<td>Dry</td>
<td>Green</td>
</tr>
<tr>
<td>1995</td>
<td>379.3</td>
<td>421</td>
<td>947</td>
</tr>
<tr>
<td>2000</td>
<td>384.5</td>
<td>428</td>
<td>988</td>
</tr>
<tr>
<td>2005</td>
<td>389.9</td>
<td>443</td>
<td>1025</td>
</tr>
<tr>
<td>2010</td>
<td>395.2</td>
<td>451</td>
<td>1061</td>
</tr>
<tr>
<td>2015</td>
<td>400.6</td>
<td>466</td>
<td>1097</td>
</tr>
<tr>
<td>2020</td>
<td>405.9</td>
<td>473</td>
<td>1134</td>
</tr>
<tr>
<td>2025</td>
<td>411.3</td>
<td>488</td>
<td>1170</td>
</tr>
</tbody>
</table>
degradation of plant species (Minson, 1990). So, along with decreased digestibility, the palatability of pastures will also be affected. In this area research should be intensified to deal with the declining quality of pastures otherwise it will have adverse impacts on food security and incomes through reductions in the production of milk for smallholders. For this the government should make considerable investment in research on fodder crops and pasture flora. It is also important that, due to increase in water shortages caused by global warming, transition will have to be made from feeding of highly palatable crops which require higher quantities of water for their growth to those fodder crops that grow well on less water such as guar, cowpea, bajra, hybrid napier grass, sudan grass etc.

**Breeding policy:** In the changing climatic conditions, it becomes imperative to review and re-orient the breeding policies. In this section, the authors discuss about the myths associated with certain recommended measures for adaptation in breeding policy as well as ground realities and possible adverse effects of such policies.

Many researchers have criticized the current policy of indiscriminate breeding of indigenous breeds with breeds from temperate regions. In spite of their adaptive characters like heat tolerance, ability to survive, grow and reproduce in the presence of poor seasonal nutrition, parasites and disease, indigenous breeds are rarely covered by structured breeding programmes (FAO, 2007). Collier *et al.* (2008) suggested some opportunity to improve heat tolerance through manipulation of genetic mechanisms at cellular level. So, the generally accepted adaptation strategy is to improve productivity traits while maintaining adaptive traits. There is a constant need to improve productivity since increasing demand will need to be supplied from a relatively non-increasing land and water resource base. Current animal breeding systems are not sufficient to meet this need and the improvement of breeding programs under different livestock production and marketing contexts is a critical area for new research. It can be contended from the above arguments that current milk production will be hampered if this policy of crossbreeding is abandoned and therefore considerable research is required in this field. The preservation of existing animal genetic diversity as a global insurance measure against unanticipated change has not been as well appreciated as has that for plants. When conservation through use is insufficient (as is the widespread situation with indiscriminate cross-breeding), ex-situ, especially in vitro, conservation needs to be considered as an important component of a broad-based strategy to conserve critical adaptive genes and genetic traits. The science for this has improved significantly in recent years and many developed countries are establishing national cryo-banks (Thornton *et al.*, 2007).

The above described adaptation and mitigation strategies for genetics and breeding may not hold true completely for Indian farmers especially, small land holders dairy farmers. In dairy cattle, it may be difficult to combine the desirable traits of heat tolerance with high reproduction and production (Ravagnolo and Misztal, 2002). The above fact emphasises that the indiscriminate crossbreeding of indigenous breeds with exotic breeds should be reviewed as Indian livestock production is dairy centric. A recent study in India showed that crossbreeding of defined indigenous breeds like Gir, Tharparkar and Sahiwal should be inarguably stopped. Also, in view of stagnated performance over generations of crossbreeds which are comparable to defined indigenous breeds depending on level of input use and negligible genetic gain per annum in crossbred population since introduction of massive crossbreeding programme (1960 onwards), it can be recommended that grading up of non-descript indigenous breeds should be done with defined indigenous dairy breeds which will result in maintenance of adaptive characteristics of both breeds of *Bos indicus* cattle alongwith concomitant increase in milk production (Misra and Mandal, 2010). At least this policy should be adopted in drought prone and rain fed regions where fodder and water availability is poor.

### TABLE 3: Decline of permanent pastures and grazing land with increase in cattle population

<table>
<thead>
<tr>
<th>Year</th>
<th>Permanent Pasture &amp; Grazing land (1) (in million ha.)</th>
<th>Gross sown area (2) (in million ha.)</th>
<th>(1) as %age of (2)</th>
<th>Cattle + Buffalo Population (in millions)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1951-52</td>
<td>8.59</td>
<td>133.23</td>
<td>6.45</td>
<td>198.70</td>
</tr>
<tr>
<td>1961-62</td>
<td>14.08</td>
<td>156.21</td>
<td>9.01</td>
<td>226.80</td>
</tr>
<tr>
<td>1972-73</td>
<td>12.71</td>
<td>162.15</td>
<td>7.84</td>
<td>235.70</td>
</tr>
<tr>
<td>1982-83</td>
<td>11.87</td>
<td>172.75</td>
<td>6.87</td>
<td>262.23</td>
</tr>
<tr>
<td>1992-93</td>
<td>11.07</td>
<td>185.70</td>
<td>5.96</td>
<td>288.79</td>
</tr>
<tr>
<td>2003-04</td>
<td>10.49</td>
<td>190.08</td>
<td>5.52</td>
<td>283.10</td>
</tr>
<tr>
<td>2007-08</td>
<td>10.39</td>
<td>195.83</td>
<td>5.30</td>
<td>337.50</td>
</tr>
</tbody>
</table>

Source: Ministry of Agriculture, GoI, 2010
An editorial published in a newspaper, THE HINDU, tells about the gross failure of the breeding policy (Sainath, 2011). According to editorial, in just three of the six crisis districts of Vidarbha region of Maharashtra where crossbreds of exotic cattle such as Jersey and Holstein were provided to the poor Adivasis at 75 per cent subsidy under Prime Minister’s relief package, “509 animals were dead. 473 were sold and 1867 could not be verified” as still being with the stated owner. That’s nearly 28 per cent of “10,210 animals distributed during the package period” of 2006-07 to 2009-10. The main reasons for these results were poor adaptability of crossbreds to higher temperatures, frequent health ailments and higher consumption of fodder and water by crossbreds which the poor farmers could not afford. So, it is clear that the policy of indiscriminate crossbreeding should be completely stopped in drier areas where there is poor availability of feed, fodder and water. Therefore, instead of providing subsidy on crossbred cattle, the government should provide subsidy on defined indigenous dairy breeds like Gir, Tharparkar, Sahiwal, Kankrej etc. So, the present policy of indiscriminate crossbreeding of local cattle with exotic cattle should be reviewed and reoriented for smallholder dairy farmer.

Water management for livestock sector: In future, water should get high priority against any other commodity. Water in agriculture sector is mainly used for crop cultivation and livestock rearing. The allocation of water to these two sectors is determined at the household level not at macro level. But due to climate change water use efficiency of crop and livestock will also decline. Cow’s water requirement increases significantly as the environmental temperature increase and cows consume up to 50 per cent more water when the THI is above 80 units (Pennington and Van Devender, 2004). Water is the most important nutrient in minimizing heat stress since it acts as a heat sink; therefore, heat is transferred from the cow’s body to the ingested water. Researchers like Linn (1997), Valtotra (2003) have proposed the measures for drinking water management. Further, water management should also be done in agriculture to prevent its wastage and optimize its use. Plethora of studies (Brown and Hansen, 2008; Debaeke, 2002; Tychon et al., 2003) have proposed the measures for water management in agriculture.

It is suggested that drinking water management should contain clean and fresh water; there should be enough water space available; there should be at least 2-3 inches of water space per cow; there should be more than 1 water device for each group of cows which may encourage water consumption and decrease competition; fresh water should be made available to cows after milking; an adequate quantity of water should be available.

Approximately 55 per cent of gross cropped area in India during 2007-08 was rainfed. Management strategies in rainfed agriculture are based on producing more food per rainfall unit in a durable manner. They can be categorized as: (i) collecting the maximum rainfall (water harvesting, runoff reduction, early planting, fallow, use of recycled water from other sectors, etc.); (ii) minimizing water loss (evaporation reduction by mulching or rapid crop cover, windshields, minimum tillage, weeding, etc.); and (iii) using water efficiently (low water consuming crop species, fertilization adapted to the water available, disease and pest control, optimal planting and seeding, selection of varieties able to accomplish their cycle within the length of the climate growing period, etc.). For irrigated land, improved management of water resources through the introduction of simple techniques for localized irrigation (e.g. drip and sprinkler irrigation), accompanied with infrastructure to harvest and store rainwater, such as small superficial and underground dams, tanks connected to the roofs of houses, etc.

While the above recommended practices may seem novel, these are not sustainable for smallholder dairy farmer in India. The reasons of this opposition may be enumerated as follows: firstly, it is very difficult for smallholder farmer to provide for additional water as this will entail additional expenses such as electricity, pump sets etc. and the already poor farmer would find harder to pay for these additional costs. Secondly, as the global warming is itself thought to increase the incidence of droughts (IPCC, 2007); with the declining per capita availability of water i.e. from 5400 m$^3$ in 1951 to 1900 m$^3$ in 2000 and corresponding rise in livestock population, water availability for livestock is bound to decrease in India. Also, the requirement of water for zebu cattle will increase in hotter climate (NRC, 1981). But the water requirement will be lesser as compared to crossbred cattle. If we consider the virtual water requirements, the study from Gujarat showed that, producing 1 kg of milk required at least more than 3000 m$^3$ and 1600 m$^3$ of water in case of buffalo and cattle, respectively (Singh et al., 2004). In the value addition process, the requirement of water will be more than liquid milk.

A simple method for alleviating heat stress in Indian conditions is to graze the animal in an area having good shade, good pasture and near a water source such as pond, lakes etc. Another option is to control the rapidly growing population of crossbred cattle which require higher quantities of water than the indigenous cattle. But for this, milk production has to be compromised (Mathew, 2008).
For irrigated lands, erosion of watersheds (dam) is a major area of concern which can affect the livelihoods of poor smallholder farmers. Many crops such as rice, which is a staple food for most of Indians requires a virtual water of 3000 litres for a production of 1 kg (Bouman et al., 2007). Such crops put a heavy pressure on ground water and make its replenishment very difficult. The following table presents total water demand projection for various sectors and their percentage utilization from ground water.

As per Table 4 bulk of water requirement for irrigation is met through groundwater which will further constrain the already declining water table. This calls for efficiency in irrigation. The rapidly increasing human and livestock population will further aggravate the situation. Also, the projected water demand for livestock will be 2.8 and 3.2 BCM in 2025 and 2050 respectively as compared to 2.3 BCM in 2000. So, proper research should be conducted to develop the crops which require lesser water. The area covered under micro irrigation in India was only 3.88 million ha i.e. approximately 2 per cent of gross cropped area and 4.45 per cent of irrigated area. Water table has decreased from 30-40 feet to 60-100 feet over last 30 years. So, in near future situation regarding efficiency in irrigation will remain grim. The government should undertake the building of dams after proper risk assessment and also the government should ensure the participation of all stakeholders (including smallholders) in decision making.

CONCLUSIONS

Smallholder farmers play an important role in livestock production in India. These farmers are resource poor and are increasingly diversifying their sources of income by increasing their livestock holdings. As global warming is increasing, new adaptation and mitigation strategies will come in vogue. So, the adaptation research should get prime attention. Ex–ante economic evaluation of adaptation and mitigation strategies should be done before disseminating the knowledge of these strategies to farmers as the smallholder farmer will only go for cheap adaptation strategies. Most of adaptation and mitigation strategies relate to developed countries which are not economically viable for smallholder farmers of India. Appraisal of smallholder farmers’ responses who are under resource-poor conditions about the adaptation strategies should be done through surveys so as to identify and rectify the errors committed in designing and implementing the adaptation and mitigation strategies. This will increase the adoption of strategies by the farmers.

REFERENCES


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<table>
<thead>
<tr>
<th>Sector</th>
<th>2000 Total BCM</th>
<th>% age from groundwater</th>
<th>2025 Total BCM</th>
<th>% age from groundwater</th>
<th>2050 Total BCM</th>
<th>% age from groundwater</th>
</tr>
</thead>
<tbody>
<tr>
<td>Irrigation</td>
<td>605</td>
<td>45</td>
<td>675</td>
<td>45</td>
<td>637</td>
<td>51</td>
</tr>
<tr>
<td>Domestic (including for livestock)</td>
<td>34</td>
<td>50</td>
<td>66</td>
<td>45</td>
<td>101</td>
<td>50</td>
</tr>
<tr>
<td>Industrial</td>
<td>42</td>
<td>30</td>
<td>92</td>
<td>30</td>
<td>161</td>
<td>30</td>
</tr>
<tr>
<td>Total</td>
<td>680</td>
<td>44</td>
<td>833</td>
<td>43</td>
<td>900</td>
<td>47</td>
</tr>
</tbody>
</table>

Source: Amarasinghe et al., 2007


