Energy Use and Women's Work in Agriculture

Reducing Greenhouse Gas Emissions

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Changes in women's use of energy in agriculture, in the spheres of crop production and social reproduction, can bring about a reduction in greenhouse gas emissions. Two technological changes—the shift from household cooking with carbon-emitting solid biomass fuels to liquified petroleum gas as a clean cooking fuel; and the shift from methane-emitting flooded rice cultivation to the System of Rice Intensification with electricity-based alternate wetting and drying—have been considered in this regard. The changes in women's roles and energy use accompanying these technological interventions have been examined.

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This is an exploratory paper in understanding the connection between women's work in agriculture—including within agriculture, both crop cultivation and what is usually called social reproduction or domestic work—and the way in which energy use can bring about a reduction in greenhouse gas (GHG) emissions from agriculture. The fieldwork used in this paper comprised focus group discussions (FGDs) mainly, including women, but also some men, in villages of Wayanad district in Kerala, Dindigul district in Tamil Nadu, and Mayurbhanj and Koraput districts in Odisha from 2015 to 2017. We also met officials of various state agricultural departments, and local liquified petroleum gas (LPG) dealers. In order to set the scene for the role of changes in energy use and women's work in agriculture, we first outline the contours of reduction in GHG emissions.

Reducing GHG Emissions

Reduction of GHG emissions can be brought about in a number of ways. First, is to reduce emissions by reducing the energy intensity of production, for example, a shift from extracting groundwater to utilising surface water, or a conjunctive use of groundwater and surface water. This change would reduce the energy required in agricultural production and depending on the emissions intensity of the energy used, whether diesel or electricity, there would be a reduction in GHG emissions.

The second way in which emissions can be controlled is to reduce the emissions intensity of energy used, by shifting from cooking with GHG-releasing wood fuel to cooking with LPG; or from inorganic to organic fertilisers. LPG, for instance, has very low emissions, or a lower carbon footprint, compared to wood or kerosene. Though it is a fossil fuel and thus will be depleted over time, it nevertheless has the advantage of almost negligible current emissions.

The third way is by reducing the input intensity of production, which is the same as increasing the input–output ratio in production. In this way, with the same emissions intensity per unit of input, such as inorganic fertilisers, there would be fewer emissions per unit of output. This could occur through adopting a technology that provides more crop per unit of input, or which requires less seed per kilogram of output. In both cases, emissions per unit of output would be reduced.

A fourth way in which a sector such as agriculture could reduce GHG emissions, is by increasing sequestration of carbon. Increased sequestration of carbon could be achieved in agriculture by adopting appropriate land use shifts, and by utilisation of bio-inputs like bio-fertilisers to augment the carbon sequestering capacity of the soil. Organic farming practices and agro-forestry-based farming systems can increase sequestration of carbon. An increase in the area under forest or the density of forest cover brought about by switching from wood fuel to LPG would also increase the sector's contribution to carbon sequestration, and thus reduce global GHGs in the atmosphere.

The two technological changes we are considering in this paper are the System of Rice Intensification (SRI) in the sphere of production, and the shift from cooking with wood fuel to LPG in the sphere of social reproduction. The former is expected to result in a reduction in the emission of methane, a GHG; while the latter is expected to eliminate the release of various forms of carbon, including black carbon, which occurs in cooking with wood fuel. By increasing the extent of forests or their density, this shift to LPG would also increase the contribution of agriculture to carbon sequestration.

Both the technological changes, in rice cultivation and cooking, operate at the household level. They are instances of private production of public goods. In looking at the adoption and use of these technologies, we consider the manner in which the roles of women's and men's labour change, and the manner in which paid and unpaid labour interact with energy use.

Study Areas and Methodology

The study areas were chosen from among sites where the M S Swaminathan Research Foundation (MSSRF) has field staff, in order to provide different levels of rural commercial development. Koraput and Mayurbhanj in Odisha are poorly developed areas mainly populated by indigenous peoples or Scheduled Tribes (STs). Wayanad is a more remote and not-so-commercially developed part of Kerala, again with a high proportion of indigenous peoples, while Dindigul in Tamil Nadu is the most commercially developed of the study areas.

Over a period of two years (2016–17), FGDs were conducted with women, including women in groups, such as Kudumbashree in Kerala and self-help groups (SHGs) in Odisha and Tamil Nadu. These FGDs, and the study itself, are part of an overall study on "Gender and the Political Economy of Energy" being conducted by the MSSRF under the United Kingdom's Department for International Development (DFID)-supported Energia research programme.

Rice Cultivation and GHG Emissions

In order to deal with climate change and develop resilience, the Food and Agriculture Organization uses the term climate-smart agriculture (CSA), which is agriculture that sustainably increases productivity, strengthens resilience (adaptation), reduces/removes GHG emissions (mitigation) and enhances achievement of national food security and development goals (FAO 2011).

Rice is the principal cereal in Asia. The manner in which rice is conventionally cultivated involves flooding of fields, leading to the production of methane gas and nitrous oxide, both GHGs. This system of rice cultivation also uses a lot of water, often pumped either with diesel engines, or with electricity generated by burning coal. Recent studies suggest that rice is an important anthropogenic source of both methane and nitrous oxide (Kakumanu et al 2016). Of the two, methane is particularly important in global warming since it traps 84 times more heat than carbon dioxide (FAO 2016).

Along with the alternate wetting and drying (AWD) of rice fields—initiated in Madagascar and subsequently developed at the International Rice Research Institute (IRRI)—new "climate smart rice production systems" have been developed (Tapan et al 2014; Kakumanu et al 2016). There are numerous variations, but the basic principle of climate smart rice production is that fields are not continuously flooded (which is what leads to the production of methane). Climate smart rice systems based on AWD, are one of the key components in the SRI package.

Rice Cultivation: System of Rice Intensification

SRI can be employed to impact GHG emissions in two ways. One way is to reduce the energy intensity of rice production. This is done by reducing water requirement, from the amount pumped in traditional rice cultivation, to a lesser amount required by the AWD method. The water requirement in SRI is less than that of the conventional rice cultivation method (Stoop et al 2002; Uphoff 2002; Thakur et al 2010; Geethalakshmi et al 2011; Jain et al 2013). A study quantified this amount to be 22%–25% less than that of conventional rice cultivation (Lakshmanan et al 2012). The Tamil Nadu Agricultural University (TNAU) estimates that the average water requirement reduced from 1,100 to 700 millimetres with SRI, or by almost 30% (TNAU, "Water Management"). With respect to required fuel usage, a study by Gujja and Thiyagarajan (2009) found that SRI reduces fuel consumption for pumping water by 30 litres of diesel per hectare. We do not have an estimate for the reduction when electricity is used for pumping groundwater.

Although the total energy required for pumping groundwater may be less in SRI, electricity or fuel is required in a definite time sequence. After the field has been dried—for a period of 1–10 days, depending on soil type, weather and crop growth stages—it needs to be quickly, flooded again. If electricity is not available at the right time, crop growth is severely affected. Uncertainty of electricity is cited as a major reason for not adapting SRI (Geethalakshmi et al 2016). Consequently, reliability of electricity supply comes up as a key precondition for widespread adaptation of the energy-saving SRI utilising groundwater. Gujja and Thiyagarajan (2009) estimated that the adoption of SRI in India in 25% of the rice cultivation area would help save about 20 billion cubic metres of water and 632.61 million kilowatt-hours of electricity.

The other and more important manner in which SRI impacts methane emissions is through the elimination of flooding of fields. Flooding in the conventional method of rice cultivation leads to methane emissions. In the SRI method, the AWD eliminates flooding, increases aeration, and reduces the time in which methane gas is produced in the wet fields by reducing the activity of methane-producing bacteria. SRI has been found to reduce methane gas emissions by 36%–64% (Geethalakshmi et al 2016). A study by Jain et al (2013) found that SRI reduced methane emissions by 28%. Reductions in methane emissions have been reported in Thailand, China and India, with the highest reductions reported from India (Geethalakshmi et al 2016). Kakumanu et al (2016) found that methane emissions were reduced by up to 50%. On the negative side, however, it should be pointed out that aerobic conditions created by AWD in SRI, trigger emissions of nitrous oxide, another harmful GHG. The field experimental data on the net result of the reduction of methane and increase of nitrous oxide under different irrigation regimes are limited. However, another recent study by Sander et al (2014) points out that the increased GHG effect from nitrous oxide is less than the reduction from methane emission under the flooded irrigation system, as long as excessive nitrogen is not introduced through high doses of inorganic fertiliser in SRI cultivation.

SRI also reduces the quantity of inputs, seed, water, and energy required for rice production. We have discussed the reductions in water and energy above. Seed requirement is reduced, as a single plant per hill is grown in deliberately spaced intervals of 25 x 25 centimetres (cm). Each plant grows to full potential yield, that is, 20%–50% higher yield than conventional flooded rice (Uphoff 2007; Thakur et al 2014). But, in Mayurbhanj in Odisha, the overall yield per acre is not very different from that in conventional rice cultivation. Discussions with agricultural officials in Odisha revealed that the increase in yield was not more than about 10%. Thus, there is a problem in that AWD or other agronomic practices in SRI have not been consistently adopted and thus there was no substantial increase in yield per acre compared to conventional flooded rice production. The same trend was observed in Tamil Nadu (Geethalakshmi et al 2016).

With land being the critical input that is limited, farmers seek to increase their yield per unit of land. Technology, which brings about substantial increases in yield per unit of land, tends to spread easily and is adopted without much persuasion. For instance, indigenous farmers in Mayurbhanj, Odisha, said that transplanting yielded about 50% more than broadcasting, which is why they quickly adopted this method in flat and well-watered lands. But SRI yield is not visibly different from conventional transplanting. The truncated SRI method of line transplanting without alternate wetting and drying also does not provide such a visible increase in yield and reduction in methane emission.

Women's Labour in SRI

With regard to women's labour, the technological change of SRI affects two areas of women's work in traditional rice cultivation. The first is transplanting and the second is weeding. Both of these are tasks in which women are employed in large numbers in conventional rice cultivation. With SRI, the transplanting (now called line transplanting), becomes more exact and requires higher skilled labour than traditional transplanting. The skill required pertains to the exact planting of just one plant per hill, in a carefully delineated distance of 25 x 25 cm between rows and columns. In addition the seedlings planted are younger than in conventional transplanting, that is, 8–10 days old single seedlings as compared to the 25–30 days old seedlings planted in a bunch. In the usual manner in which women are supposed to be low-skilled or even unskilled, the task of marking the distances and lines is carried out by men, while women do the actual transplanting. Since the seedlings are younger and spacing more exact, there is an increase in the number of women days of employment required for transplanting. But, the guiding of the whole process of line transplanting is carried out by men. This is not a displacement of women by men, but an addition of men in a supervisory role, into what was formerly exclusively the women's task. It is interesting that this is done despite the usual identification of women with nimble fingers, a factor used to justify women's employment as low-paid workers in garment production.

Conventional flooded rice production reduces the need for intensive weeding and it is common for manual hand weeding to be done twice early in the season. But, with SRI, due to the alternate wetting and drying, more weeds grow in the fields and thus need frequent weeding, along with incorporation of the weeds into the soil and aerating the soil. Weeding is often the women's task in agriculture. In SRI, however, the weeding is done with a machine, a cono weeder, which is manually operated; electric, or diesel-powered machines are not commonly used.

Weeding using mechanical implements is highly recommended in SRI, as mechanical weeders disturb the soil near the root surface, thereby activating soil aeration to promote growth of roots and aerobic soil biota (Gathorne-Hardy et al 2013). But, the usual gendered definition of women as not being adept with using machines comes into play, making cono weeder operation a men's task. Operating the cono weeder in the semi-dry soils produced under SRI is said to require more physical strength, something that men are said to possess more of, in relation to women. There is a clear tendency for SRI weeding to be done with machines, even manually operated ones. With this mechanisation, there is a tendency for men's labour—as supervisors and machine operators—to replace women's labour.

A lot of agricultural equipment is bought with subsidies provided by the government. Our investigations with agricultural engineering departments in Odisha, Kerala and Tamil Nadu showed that, in each case, such subsidies are given to those who can provide land title deeds to show that they are farmers. Women, who generally, do not own land, are excluded from owning the agricultural equipment bought with subsidies. In Odisha, we discovered a novel way employed to get around this problem. In order to be able to claim the higher subsidy usually available for women, men were transferring ownership of a small plot of land to their wives, to meet the eligibility criteria. With this land in their names, women could be classified as farmers and were thus eligible for this higher subsidy.

To sum up the impact of the switch from conventional to SRI rice cultivation on women's labour, there has been an increase in the requirement of skilled labour, whether in line transplanting or in weeding, and such skilled work gets shifted into the domain of men's work, while women are displaced from such work. Whether in line transplanting or weeding, even on small plots of land, mere family labour is insufficient. Along with family labour, large numbers of women are employed in both transplanting and weeding. The wage cost of weeding one hectare is a maximum of ₹2,400 with a cono weeder, with eight men paid ₹300 for a day, as against ₹7,500 with manual weeding, with 50 women paid ₹150 for a day. Where women are employed as wage labourers, therefore, there is a tendency for them to be displaced when the task requires labour that is somewhat more skilled.

Household Decision-making on SRI

Reduction in GHG emissions is a global public good, but given that a reduction in GHG emissions is privately produced, there would need to be a sufficient yield incentive for GHG-reducing SRI to be widely adopted by farmers. Subsidies can help reduce the risk involved in technological transitions, but subsidies cannot be the method through which technological changes are sustained. Thus, research and development (R&D) needs to concentrate on increasing yields per unit of land under SRI, so that farmers may adopt it on a wide scale.

Given that even in folk understanding women are not considered farmers, with regard to the trial and adoption of SRI, there does not seem to have been much role for women in the formal decision-making. Discussion in a village in Mayurbhanj, Odisha—where a truncated version of SRI involving just line transplanting is being used—showed that following the usual pattern, men take decisions on the technology or cultivation method to be adopted and, at best, inform their wives about their decisions. Where the MSSRF was involved, the training of women farmers in SRI helped them participate in household discussions on technological change (Rengalakshmi and Nagothu 2016).

As mentioned above, water control and labour constraints in the initial phase are the two factors that seem to inhibit the adoption of SRI on a regular and wide basis. The first constraint is due to poor electricity availability, with no guarantee that it will be available at the times required for wetting the fields. Since water control is an absolute requirement of the SRI method, reduced but reliable amounts of water at intermittent intervals has to be ensured. The other factor is weeding using a cono weeder to increase the aeration in the root surface. Controlled studies show clear gains for SRI over conventional flooded rice cultivation (Katambara et al 2013; Kassam et al 2011; Zhao et al 2010; Satyanaryana et al 2007; Kabir and Uphoff 2007; Sato and Uphoff 2007; and Latif et al 2005), but it is likely that the SRI practices are very substantially modified by farmers. Agriculture department officials pointed out that farmers have always been tinkering with spacing, or the days of transplanting, motorisation of weeders, and were not adopting all of the six practices that constitute SRI. From a GHG emission point of view, water control and weeding are the two components which need further research and development for wider adoption.

But, why is it that, despite a reduction in water and energy used—that is, an input reduction of up to 25%—greater adoption of this less-input-intensive technology has not been seen? The reason is that neither water nor electricity for agriculture are priced. As a result of the unpriced nature of these inputs, there is no private incentive to economise or reduce input use. At the same time, there is also inadequate investment in improving the power infrastructure and maintenance, resulting in poor quality of supply, which is of low voltage, unreliable and untimely. This has negative implications for farmers, and inhibits their adoption of controlled irrigation, discouraging the consideration of more efficient systems and practices (Rasul 2016).

Reform of both water supply and energy pricing systems, in order to price the water drawn and cost the energy used to draw it, could promote a wider adoption of SRI. It should be noted that pricing of groundwater does take place, and as pointed out in Birner et al (2011) some market for groundwater has developed. In addition, depletion of groundwater increases the cost of sinking tube wells. But, even with such developments, there is a need for pricing groundwater in order to promote the adoption of economising technologies.

While unpriced or subsidised inputs, water and energy are overused, farmers try to economise on the use of land and labour, both of which have a price. Farmers seek to maximise output per acre, irrespective of water and energy used. They also try to economise on the use of priced labour, substituting mechanical equipment like cono weeders for women's wage labour.

Cooking and GHG Emissions

The sector we are dealing with is agriculture, which is conventionally defined to include not only crop production but also livestock rearing, fisheries and forestry. Agriculture is also conventionally defined to exclude domestic care work. Social reproduction, in this manner, is separated from production. But, a holistic view of production would include what is called social reproduction, or care work, within its ambit. The latter is part of the overall process of social production, required specifically to produce and reproduce labour itself. Thus, in this paper we include care work, largely done by women within agrarian families, as part of the agricultural sector. This is an attempt to endogenise all of women's labour.

Of course, there is a difference between conventional production and care work, in that the former yields income, either in cash or goods, while care work within the family does not yield such an income. But, in agricultural production too, women's work on family farms is part of unpaid family labour. Only women's work as wage labourers, or when they are self-employed, yields an income and such work is considered different from unpaid work. This difference between paid and unpaid work will be seen to have an impact on the extent of technological change in the two domains of production and social reproduction. There is a strong tendency to replace paid labour with machinery, while substitution of unpaid work with machinery is not only very slow, but is in fact seen to be dependent on the extent of paid work performed by women.

The share of solid biomass (wood, agricultural waste, animal dung) in India's primary energy mix was 14.5% in 2012 (Ahluwalia et al 2016). This is quite high. Most of it is used for household or domestic cooking, although some is used for commercial production, such as sugar cane bagasse used in boilers in sugar factories or in the small-scale commercial production of puffed rice. In 2011–12 (the last year for which we have reliable nationwide data), wood was the primary source of energy used for cooking by 76.3% of rural households, while for 9.6% of rural households, dung was the primary fuel (NSSO 2015: 14).

Burning of wood has negative effects, both at the global and at the local, household level. It leads to the emission of GHGs (carbon dioxide, carbon monoxide and black carbon) into the atmosphere, and thus contributes to global warming. It also has local effects through the release of these gases and particulate matter on household air pollution. This household air pollution leads to respiratory, pulmonary and vision problems. These negative effects are mainly felt by women, who do the cooking by burning wood, and children who stay around the women.

The World Health Organization (WHO) estimates that in India more than 1 million (or 10 lakh) deaths per year in 2011–12 were due to household air pollution from using solid biomass fuels (Global Alliance for Clean Cookstoves 2017). A careful survey of a large group of scholars from many countries puts together data on the global assessment of household air pollution due to cooking with solid biomass fuels, and shows that it is an important health hazard in the rural areas of low income, and even in some middle-income developing economies (Smith et al 2014).

As in the case of methane emissions from rice cultivation, carbon emissions from cooking with wood fuel too, are produced by the individual actions of women cooking with solid biomass fuels across rural areas of developing countries. But, there is a difference between the two cases in that cooking with solid biomass has local and household effects on health, morbidity and mortality, while methane emissions from rice cultivation are not known to have such effects. Does this mean that the elimination of household air pollution by switching from wood to a clean fuel, such as LPG or electricity, would be easily achieved? A look at the record of India belies any belief in such an easy transition. The proportion of rural households cooking with wood fuel fell by only 11 percentage points, from 78.3% in 1993–94 to 67.3% in 2011–12 (NSSO 2015).

Our case studies in Dindigul district in Tamil Nadu, Wayanad in Kerala, and Koraput and Mayurbhanj in Odisha show that there exists a pattern to rural fuel use in cooking. We summarise here what has been detailed in Nathan et al (forthcoming). Where there is pressure on women's time because they are very much involved in income-earning labour—as observed in Dindigul or some cases in Wayanad—provision of a capital subsidy for LPG resulted in women switching from wood fuel to LPG as the primary cooking fuel. The number of cylinders they ordered was around 10, or even 12 per year.

But, in areas where women did not substantially participate in income-earning activities—as in the two districts of Odisha and some parts of Wayanad—there was a tendency for an LPG capital subsidy to result in fuel stacking, rather than fuel switching. Wood remained the primary fuel for cooking the main meals, while LPG was used for reheating food or preparing tea. The number of cylinders ordered by such women tended to be around two to four in a year. A recent enquiry in Mayurbhanj about recipients of the Pradhan Mantri Ujjwala Yojana (PMUY)—that is, those who received free connections and equipment under the central government's scheme for women below the poverty line—showed that many such women had not ordered any refills at all over the period of one year. An investigation by the environmental magazine *Down to Earth* in August 2017 concluded that promoting refilling is the toughest part. The report quotes an LPG distributor in Shravasti district of Uttar Pradesh who stated that barely half of the PMUY beneficiaries have come back for their LPG refill, and that too, just once or twice. Another LPG distributor in Dindori district of Madhya Pradesh says, "The refilling rate is quite low. It is not more than 7% in the district." They point out that "officials of the LPG marketing companies admit that the low refill booking and commercial diversion of cylinders are areas of concern" (Pandey et al 2017).

The key data, which summarises the difference between fuel stacking and fuel switching, is that, in the case of fuel stacking, two to four LPG cylinders are ordered, as compared to the 10 to 12 ordered in the case of fuel switching. The central factor behind this change is that of an increase in the opportunity cost of women's labour, and the resulting switch to labour-saving LPG against labour-intensive wood fuel.

Integrating Women's Paid and Unpaid Labour

The answer to why the transition in rural cooking energy is so slow depends on what cooking and conventional rice cultivation have in common. Namely, that critical inputs—women's labour in the case of cooking, and water and energy in the case of conventional rice cultivation—are not priced. Women's labour in cooking is part of domestic work and, as such, is unpaid labour. Even its opportunity cost in terms of the alternatives that could be earned with any labour saved is very low, particularly in poorly developed, remote rural areas. Water and energy are both free, and thus overused in conventional rice cultivation. Similarly, women's labour is unpaid or free, in a monetary sense, and thus also overused and not recognised as work in the case of cooking with collected solid biomass.

Our analysis also showed that there is a connection between paid and unpaid labour, and energy use. The more women are involved in paid labour, the more they economise on unpaid labour in cooking. The switch from wood fuel to LPG, it should be noted, is also a switch to a less labour-intensive method of cooking. Cooking with wood fuel involves many hours spent collecting wood, more time in cooking itself, and then a lot more time in cleaning vessels. Even women who purchased wood mentioned that the saving of time usually spent cleaning utensils was a big factor in their switch to LPG.

In the case of SRI, there is a tendency to economise on women's paid labour by switching from employing women as weeders, to use of the mechanical cono weeder operated by men. In addition to saving labour time, the cono weeder is also preferred in the SRI because it disturbs the soil and increases aeration, which inhibits production of methane gas. The mechanisation of women's paid labour is to be expected, as women's paid labour would be subject to the usual economic calculus of monetary cost. In the case of cooking fuel, women's unpaid labour in collecting fuel and cooking is also subject to an economic calculus, but one based on opportunity cost. The higher the opportunity cost of women's labour, the more likely are labour-saving methods to be adopted in cooking.

Upon considering conventional labour of agricultural production, with domestic labour, we are able to see the interactions between paid and unpaid labour. Past analyses of women's unpaid labour have largely concentrated on the limitations to women's labour force participation, as a result of their involvement in unpaid, domestic labour, that is, in understanding how unpaid labour frames women's labour force participation. Diane Elson (2008) refers to reducing the drudgery of unpaid work in order to be able to "enjoy leisure or to participate in productive work" (Hirway 2015: 14).

The analytical objective is to "incorporate unpaid work in understanding the functioning of labour markets" (Hirway 2015: 20), since the nature of unpaid work will influence many aspects of women's labour force participation, including choice of work, mobility, etc, that denies them a level playing field with men in the labour market (Hirway 2017: 373).

We are, however, dealing with the obverse side: how does women's labour force participation impact women's performance of unpaid tasks? In this, our analysis differs from a supply-side analysis based on the availability of labour-saving appliances. For instance, Antonopoulos and Hirway (2010: 4) point out, "the exact duration and distribution among tasks of 'household reproduction time' … is determined, to a large degree, by income levels and availability of household appliances." In the case of cooking appliances, LPG systems are not just unavailable, but even where they are actually installed within households, their use is restricted by women's own low-income earning. Of course, higher income earning need not translate into the adoption of labour-saving appliances. We would have to see whether income earning translates into changes in both social norms about cooking fuel and in women's empowerment (Nathan et al forthcoming). These issues are being further investigated through household surveys in Dindigul, Wayanad, Mayurbhanj and Koraput.

Political Economy in the Production of Public Goods

The reduction of GHG emissions is a public good. Some public goods, such as a country's military and administration, or law and order, are produced centrally. The scale at which these public goods are produced is decided by governments and legislatures; they are then produced by fiat. On the other hand, the reduction of methane emissions in rice cultivation and carbon in cooking are produced privately by the decisions of hundreds of millions of rice farmers and rural households, including women, but often not as decision-makers. Their decisions on the method of rice cultivation or cooking are based on private interests interacting with market conditions and government policies. How individual or private interests can be aligned with the public interest is a key question of the political economy of reducing GHG emissions.

Reduction of GHG emissions as a public good is different from law and order as a public good. The former is a global public good, while the latter is a national public good. As with the production of any public good, there are externalities involved. Thus, a country that does not contribute to the public good would still benefit from its production. The alignment of global and national interests has been sought through the Paris Agreement and the subsequent nationally determined contributions (NDCs). As per its intended NDCs (INDCs) promise, India is expected to reduce its emissions intensity by 33%–35% from its 2005-level by 2030.

The harder task is achieving the INDCs. For instance, in the case of primary energy, the share of biomass, including agricultural waste, is required to change from 14.5% of primary energy in 2012 to 5.7% in 2047 (Ahluwalia et al 2016). Incentives come into the picture in order to bring about the required changes in production systems to achieve this target.

The problem of incentives for the production of privately produced public goods is dramatically illustrated by the issue of stubble burning by farmers in Punjab and Haryana. Burning of stubble is carried out by farmers to quickly clear harvested rice fields and prepare for the sowing of wheat. This burning produces the negative externality of dramatically raising pollution levels in Delhi and the National Capital Region (NCR). To deal with the dangerous levels of atmospheric pollution, there have been government and Supreme Court orders to ban such burning. But, these have not had much of an effect, as farmers say that, without incentives, "burning is the only way out" (Chaba 2017).

To bring about a reduction in the use of biomass for cooking, our analysis (Nathan et al forthcoming) is that the provision of a capital subsidy, as in the PMUY, needs to be supplemented by the promotion of women's income-earning opportunities. This means an increase in rural women's labour force participation, not as unpaid family workers, but as wage employees or self-employed. Income-earning capacity is likely to affect women's bargaining power in household decision-making, besides increasing the opportunity cost of their labour. Thus, with women in paid work, their private incentives to use LPG as cooking fuel will be aligned with the national and global goal of reducing wood fuel in cooking.

In rice cultivation the question is one of reducing GHG emissions through a change in the method of cultivation, that is, a shift from conventional flooding of fields to alternate wetting and drying, as in SRI. This is not a matter of a direct switch in energy used; but energy enters into the policy mix through its role of promoting or retarding the desired technological change. When energy is free, as is the case of electricity for agriculture, then there is no private incentive to economise on its use through a switch from conventional rice cultivation to SRI. The absence of a private incentive to switch technologies is even further reduced by water itself being free. On the other side, SRI requires more skilled labour, which comes at a higher wage rate than conventional rice cultivation.

Both types of incentives, those with regard to free energy and water, as well as priced labour, are aligned against the desired switch. Why is that so, and what can be done about it? With strong rural lobbies and competitive electoral politics, there has been a strong tendency, particularly in Tamil Nadu and Kerala, to increase the extent of goods and services freely distributed by the state. Diesel too has been subsidised, though at the central level. While the central government is moving to reduce and then eliminate the diesel subsidy, the free supply of electricity for agriculture is unlikely to be changed anytime soon. In order to remove the free supply of electricity (and water), it would be necessary to make agricultural and rural income growth much more stable and broad-based than it currently is. In the absence of stable rural growth, there are likely to be strong electoral reactions to any attempt to eliminate free electricity.

In addition, the supply of electricity also needs to be made more stable and regular. As pointed out earlier, irregular electricity supply is a key factor in inhibiting the switch to SRI and also increases the chances of farmers relying on the carbon-emitting subsidised diesel fuel. Overall, since the availability of electricity at the right time, and of the required voltage is critical to the adoption of the alternate wetting and drying system, the adoption of the whole complex of the SRI depends on reliability of electricity supply. In its absence, just a few practices of the SRI package are adopted, resulting in yield that is reported to be not much higher than that of conventional flooded rice cultivation. The adoption of the climate-smart SRI is crucially dependent on reliable electricity supply, which itself is connected to it being priced, so as to promote investment in developing and properly maintaining electricity infrastructure.

Thus, the whole system of incentives needs to be redesigned. For one, the subsidy for SRI, when offered, works to support the technological shift. But such a shift is not stable. When the SRI subsidy is withdrawn, the perverse incentives to overuse fuel—whether in the form of free electricity, subsidised diesel, or free water—kick in, causing farmers to revert to the conventional rice cultivation technology. As is aforementioned, the increase in yield per acre (the resource that is the biggest constraint on production), is not high enough to provide a strong private incentive to sustainably switch to SRI.

Women-specific Factors

Do women-specific factors play any role in the incentive system? It was seen that there is a tendency, even within the farm household, for women's labour in transplanting and weeding to be replaced, to an extent, by men's labour. With some mechanical equipment being used, there is the usual default norm of women's work not being considered skilled labour. Men, who are supposedly skilled, take over those roles which require the use of mechanical equipment.

But it is not only the social norm of women supposedly not being skilled. There is also the question of ownership of the equipment. All the schemes give subsidised agricultural equipment to farmers and men, who are the landowners. In fact, being a landowner is a condition for eligibility to receive subsidised equipment. This reinforces the exclusion of women from the skilled jobs using mechanical equipment.

As mentioned above, in order to benefit from the higher subsidy for women, some men in Odisha were reported to have transferred small plots of land to their wives. Ownership of any agricultural land, even less than, say, one-tenth of an acre is adequate for women to be identified as farmers, and thus become eligible for a higher subsidy. The commercial banks, which provide the loan, look not just at the tiny plot of land that the women own, but at the household's overall landholding and economic condition while sanctioning a loan. Thus, women get ownership of a plot of land, and get agricultural equipment in their names, while the household's overall economic position and land operated remains the basis for the bank loan. This method of transferring at least a small plot of land is an intermediate solution, but it is one that can work on a larger scale without requiring any legal change. It is likely that it would help to secure agricultural equipment in women's name.

However, more might need to be done in terms of recognising women as a skilled labour force. The increasing migration of men, reported even in the less-developed Mayurbhanj district, can help push for women to be trained and accepted as skilled labour. In this, responsibility lies not only with farm households, but also with government agricultural departments, which usually concentrate all their extension and training activities on men. Women should also be similarly trained in more accurate line transplanting required in SRI and in operation of the cono weeder.

In contrast to the observed displacement of women when the skill level of the task rises, we noticed that in Kerala, where women themselves undertook the purchase and ownership of machinery, a similar displacement of women from skilled work did not occur. This was in the case of mechanisation of milking and washing of buffaloes in dairy farming. Women's groups invested in the equipment and they themselves operated them, acquiring the skills needed, with men playing a supporting role, at best.

Conclusions

Interest groups clearly play an important part in policy formulation. As a result, it was shown that strong rural lobbies in Maharashtra and Punjab led to more farmer-friendly electricity policies than in Odisha (Kale 2015). In Tamil Nadu and other states, competitive electoral politics is another factor that has come into play in pushing for free electricity for agriculture.

But, beyond the role of interest groups, there is also an approach to development policy which emphasises the role of the state in providing various services. This could be a rights-based or welfarist approach, as against one of market-based empowerment (Gupta and Sharma 2006). But, as we have shown in the case of the switch to cooking with LPG, a simple rights-based approach of providing a subsidy may not be successful. Negotiation within the household is needed in order to turn access to LPG into use of LPG. Thus, rights- and market-based approaches are not necessarily exclusive of each other; effective policy could, at times, require a combination of the two.

Finally, in a market-based system of private decision-making, an input that is not priced or is underpriced will tend to be overused. This is so with regard to the overuse of free water and electricity in rice cultivation, as also with regard to women's unpaid work in domestic cooking. Prices of resources such as electricity can be adjusted. But, the inclusion of women's unpaid labour in the macroeconomic calculus still needs concerted conceptual and policy attention.

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