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Strategies to Reduce Food Loss in the Global South

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Abstract: Approximately one third of the world's food is lost, and reducing this represents an important strategy for promoting more sustainable food systems and addressing global food insecurity. This paper presents a preliminary assessment of the socio-economic factors that are significant in causing food loss in developing countries. These countries were chosen because the majority of food waste in poorer nations happens on or around the farm and is due to inefficient storage and processing facilities (by contrast, the majority of food waste in the global north is caused by consumers or retailers and, hence, is a very different problem). To explore this topic, we conducted a multivariate panel data analysis where the volume of food loss in 93 countries over 20 years was used as the dependent variable and a range of socio-economic factors were used as independent variables. Results show that, for the countries in the global south, variables related to wealth, agricultural machinery, transportation, and telecommunications were significant in explaining the amount of lost food. We used these results to model the effectiveness of different hypothetical policies designed to reduce food loss and estimate that up to 49% of food loss could be averted by improving each countries' performance on these variables. While these results seem to offer huge opportunities to improve the sustainability of global agricultural systems and address global food security, this paper concludes on a note of caution: as countries grow wealthy enough to address the food lost by challenges associated with on-farm issues, these same countries may start to experience more food waste at the consumer/retailer end of the food chain. Therefore, any attempt to reduce on-farm food loss in lower income countries must be met with policies to reduce the emerging problems of food waste amongst consumers and retailers.

Keywords: food loss; postharvest loss; global south

1. Introduction and Background Literature

Today, food-farming systems cause up to 270,000 km^2 of land/year to be deforested [1] or desertified and are associated with approximately 1/3 of the world's greenhouse gas emissions [2]. In addition, recently, the United Nations revised its population estimates and now predicts that there will be approximately 11 billion people on the planet by 2100 [3]. This sharp upward revision (previously the UN had estimated that global population would peak around the year 2050 at nine and a half billion) reignites discussions about global food security and poses the question: can the Earth provide for so many [4]?

While much of the discussion on "how to sustainably feed 11 billion" focuses on boosting crop yields and increasing farm productivity [5], a growing body of work proposes that reducing food waste is an effective strategy for improving global food security and reducing agriculture's impact on the ecosystems of the planet [6–14]. For instance, in their widely-cited paper on "solutions for a cultivated planet," Foley et al. [15] propose that reducing food waste, along with boosting production on underperforming lands and shifting diets towards less resource-intensive foods, could help double the amount of food available for human consumption while simultaneously protecting our planet's natural environment. Thi et al. [16] build on this argument by pointing out that reducing food waste in developing countries is a major opportunity to promote more sustainable development.

To contribute to this literature, our paper begins with the UN's Food and Agricultural Organization's 1981 definition that describes food waste as occurring when wholesome edible material intended for human consumption is discarded, lost, degraded or consumed by pests at any point in the food supply chain [17]. Additionally, this paper moves beyond this description by building on the more recent literature that distinguishes between two different kinds of food waste [9]. The first type is the loss of food during production and post-harvest processing and occurs mostly in the Global South. The second type is waste by consumers and retailers and is mostly an issue in the Global North.

While it is widely acknowledged that data on food waste are difficult to come by [9], what estimates we do have suggests that approximately 30% of the annual global harvest is never consumed by human beings [7]. One of the most-cited recent reports on food waste was published by the FAO in 2011 [6]. This study presents a life-cycle assessment of the global food chain and confirms previous estimates that approximately 1.3 billion tonnes of food, or a third of total global production, is lost. This study also provides a reasonably detailed account of where food is wasted, demonstrating that there are political and economic dimensions influencing where and how food waste occurs. More particularly, scholars working on this topic note that more food is wasted per capita in the Global North than in the Global South (nota bene, the term "the Global North" refers to North America, Western Europe, Australia and New Zealand as well as the developed parts of East Asia. This term is also used to refer to the "Industrialized world", the "Developed World", or high-income countries as per the World Banks Classification—see the Methods section below. Similarly, the "Global South" is used for Africa, Latin America, and developing Asia, including the Middle East) with Europeans and North Americans wasting approximately 100 kg/capita of food each year. In Sub-Saharan Africa and South or Southeast Asia only 6–11 kg of food is wasted per person per year. Furthermore, the causes of food waste differ around the world. In the Global North, the low cost of food means that a tremendous amount of food spoils before being eaten or it is simply thrown out due to taste or cosmetic issues. In the Global South, however, the causes of food loss are mainly associated with inefficient harvesting, inadequate storage and cooling facilities, as well as poor quality packing and manufacturing processes. In other words, in the developing world, food loss happens at or around the farm gate, whereas in the developed world food loss occurs closer to the consumer end of the food chain [9,18].

There have been numerous attempts to estimate the value of these losses. For instance, Buzby and Hyman [19] used USDA data to estimate that Americans wasted $165 billion worth of food in 2008. These authors further estimated that meat, poultry, and fish represented 41% of this loss; vegetables represented 17%; and dairy products represented 14%. This translates to 124 kg of food lost per capita, costing the average American $390 per year. In terms of the food waste in the Global South, Hodges et al. [20] confirm that post-harvest losses typically occur at or around the farm in the least developed countries. Hodges et al. [20] further argue that the best strategies to reduce these food losses include farmer education, better infrastructure to store food, better access to markets for small-scale farmers, and the creation of opportunities for collective marketing.

In summary, the literature on food waste demonstrates at least two overarching themes. First, since a huge proportion of food produced globally is wasted, reducing food waste represents a significant strategy to help reduce agriculture's impact on the planet while address rising global food needs. Second, although socio-economic and technological causes of food waste are very important, they vary wildly between regions. The purpose of this paper, therefore, is to use quantitative methods to assess the relative importance of the various socio-economic factors that contribute to food waste in the Global South (aka the Developing World), as a way of identifying policies that may be more effective at addressing this serious global problem. Given the focus on food waste in low-income countries, the term food waste in the rest of the paper refers to on the losses that occur in and around the farm. Our analytic process involves a statistical approach to identify and weigh the importance of different socioeconomic and technological variables in determining food waste focusing on lower income countries. We then use these calculations to provide an initial estimate as to the potential effectiveness of different policy scenarios. This allows us insight into how to reduce food waste in already food-insecure regions of the world.

2. Conceptual Framework, Data and Methods

2.1. Conceptual Framework

We begin with our conceptual framework on Brooks et al.'s [21] paper on the socio-economic determinants of adaptive capacity, Fraser et al.'s [22] paper on the socio-economic determinants of climate change vulnerability and Thyberg et al.'s [23] paper on the drivers of food waste and their implications for sustainable policy development. Briefly, all of these three papers use national level data to explore the socio-economic factors associated with the management of social ecological systems. All three papers highlight the need for robust methodology, which uses spatial and temporal data to identify multiple indicators of socio-environmental processes. One limitation of this approach is that, in these papers, the role of policy is treated in a somewhat static force that is manifest through national level socio-technical indicators such as access to different types of infrastructure. Hence, this approach leaves out more nuanced types of policies and regulations (such as pollution taxes) that may only indirectly influence the kinds of infrastructure a country develops. Notwithstanding such a limitation, this approach is valid in that it makes use of existing data and provides a preliminary way of identifying how policies that influence socio-technical and infrastructural factors may influence food loss. We draw from this literature the following preliminary hypotheses that form the basis of this enquiry.

- Gross domestic product per (GDP) is likely to be associated with food loss in the Global South. GDP is the sum of gross value added by all resident producers in the economy. GDP/capita (GDP/cap) can be used to measure consumer wealth, which has been argued to have a positive relationship with the amount of food that is lost.
- Another factor that could be associated with food loss in a country could be the levels of access to, and use of, agricultural machinery is hypothesized to create more efficient food production and processing systems and, hence, lower food loss. We hypothesize that higher levels of access to agricultural machinery lowers the amount of food loss.
- There is a considerable literature on the need for developing a better transportation in the Global South as a way of reducing food loss. For instance, Kader [24] points out that "in most developing countries, roads are not adequate for proper transport of horticulture crops..." Similarly, Parfitt et al. [9] argue that, for countries that are rapidly urbanizing, a major logistical challenge is developing the transportation infrastructure to bring food to markets quickly. Therefore, we hypothesized that countries with a more developed road network will have less food loss.
- The use of cell phones is increasingly documented in the literature as a major force that is reshaping education, health care, and agriculture in the Global South. In particular, low cost, wireless technology, is allowing people of all economic classes to help control disease [25], and is providing access to information and education [26]. Agriculture has been identified as another frontier where mobile technology is going to help small scale producers improve efficiency by identifying markets, transportation options and insurance programs [27]. Like having a well-developed road network, having good communications technology should make moving food from farms to markets more efficient and thus reduce losses. Therefore, we hypothesized that countries with better access to communications technologies will have less food loss.

2.2. Data

Twenty years of country-level data on food loss were obtained from the Food and Agricultural Organization (FAO)'s electronic database (see Table 1). While these data do not differentiate all kind of food losses and waste in all countries, FAO provides information on a range of crop, livestock, and fishery waste in many countries. Therefore, we calculated food loss per capita per year by summing up all crop, livestock, and fishery waste for each country in each year, and then dividing this figure by the population of each respective country in that year. In this way, we were able to obtain our dependent variable: the average loss per year/capita in each year for low, lower-middle, and upper middle income countries. Second, both the FAO and World Bank databases were used to obtain the socio-economic data that were used as explanatory variables (Table 1). Given the massive reorganization of countries following the collapse of the USSR, all data before the early 1990s were dropped and data were only available up to 2011. Data were transformed using the natural log in order to control for non-linearity. More specifically:

- **Wealth** was measured in US$ of GDP/Capita.
- To assess the level of a country's **agricultural machinery** we used the average dollar value of agricultural machinery per 100 square kilometers of arable land in each country.
- A country's **road infrastructure** was evaluated using "road density" as a proxy and it is assumed that countries with a higher road density have greater opportunities for more efficient transportation. We defined road density as kilometers of road per 100 square kilometers of land area.
- In order to evaluate the impacts of **communication networks** on food waste we calculated the total number of combined landline phones and cell phones used per 100 people in each country in a given year.
- As noted earlier, higher income countries were not included in this study since the causes of food waste are very different in those parts of the world. Instead, we focused on what the World Bank defines as low-income economies (those with a gross national income (GNI) per capita of <$1,045), lower-middle income economies ($1,045–$4,125), and middle-income economies ($4,125–$12,746). In total, food waste information was found for a total 35 low, 37 lower middle, and 21 upper middle-income countries, giving us an overall sample of 93 countries and 20 years of data. As expected, all socioeconomic variables were highest in middle-income countries and lowest in low-income countries (please see details in Table 1 and Supplementary Table S1).

Table 1. Summary of statistics.

Variables	Low-Income Countries *N* = 37		Lower-Middle-Income Countries *N* = 35		Upper-Middle-Income Countries *N* = 21	
	Mean	**SD**	**Mean**	**SD**	**Mean**	**SD**
Food loss (kg/capita)	44.38	38.81	55.88	36.37	65.77	43.41
Food loss (million tonnes/year)	1.25	2.47	4.20	1.25	1.93	4.26
Gross Domestic Product (US$/capita)	423.43	180.29	1733.86	814.70	4644.70	1483.92
Value of Agricultural Machinery (US$/year/100 km^2 of land area)	172.36	330.61	375.36	564.43	557.28	616.26
Road density (Kilometres/100 km^2)	17.28	20.35	26.57	30.76	31.09	27.21
Telephone density (number of landline phones and cell phones/100 people)	11.11	20.46	24.77	33.91	30.74	35.07

SD = standard deviation.

2.3. Statistical Methods

First, we used a multivariate regression model to determine the extent to which GDP, agricultural machinery, road infrastructure, and communications networks were significant in determining food loss for all low, lower-middle, and upper middle income countries. We then integrated the results of this regression analysis into a geographic information system (GIS) in order to visualize the impact of strategies to reduce food waste at individual country levels. To do this, we used previously-established methods of combining socioeconomic and spatial data [28–30] that involved the preparation of a thematic layer for the country-level dependent and explaining variables. Estimated food waste and impact maps for different scenarios were constructed by exporting the regression results back into the GIS platform.

2.4. Scenario Analysis

Significant regression models results were used to simulate the effect of policy on food loss. First, we constructed an "improved machinery" scenario. In this, we modeled the hypothetical impact on food loss of a policy that raised all countries' agricultural machinery use up to 95% of the country with the highest machine use value within each income category. In this way, we modelled the effect of a policy that caused the level of machinery use in all low-income countries to rise to 95% of the level of machinery used by the top performing low-income country. We then repeated this process for lower-middle and middle income countries. We used the same approach to simulate the impact of policies geared at improving (1) the road network and (2) the communication infrastructure. In these, we calculated the amount of food loss that would be generated if a country's road and telephone densities were increased to 95% of the best performing country within each income category. Our decision to change the values of these socioeconomic variables to 95% of the best-performing country within an income class followed Foley et al. [15] who calculated how much food could be produced globally if all areas on the planet had production values equal to 95% of the most productive area within each agro-ecological zone. One limitation of this approach is that it assumes that food loss has a linear relation with socio-economic variables and if this assumption is not correct then our scenario analysis is likely to over-estimate changes in food loss. Nevertheless, results of the scenario analysis represent a first order approximation of the potential effect of policy, and an obvious avenue for future research would be to refine this approach by using non-linear functions.

3. Results

3.1. Summary Statistics

Table 1 provides descriptive statistics for the variables in the analysis and reveals huge differences in the countries from the three economic regions. In particular, higher food losses was observed in upper middle-income countries compared to low and lower-middle income countries and here we note that average food loss from upper middle- income countries was 65.77 kg per capita (1992–2011). This is broadly consistent with the literature reviewed in the introduction, and unsurprisingly our data demonstrate that poor economic regions produced lower levels of food loss. Going into the details of these data reveal that the highest per capita food loss in low income-countries was observed in Ghana where an average of 211 kg/capita/year was lost between 1992 and 2011. The lowest food loss in a low-income country was observed in Yemen where there was only 10 kg/capita of food lost. Three low-income countries (Nigeria, Benin, and Ghana) lost over 100 kg/capita while 27 lost less than 50 kg/capita. Similarly, in the lower middle-income region, Guyana had the highest average per capita food loss (235 kg/cap/year) and three countries (Paraguay, Guyana, and Peru) each lost over 100 kg/capita. 18 out of 21 middle-income countries lost less than 50 kg and seven wasted less than 50 kg per capita while four countries (Botswana, Costa Rica, Turkey, and Gabon) wasted over a 100 kg per capita per year. The highest rate of food loss was observed in Gabon that lost an average of

153 kg/capita per year, whereas Mauritius just lost 9 kg/capita (see details in Figure 1, Table 1 and Table S1).

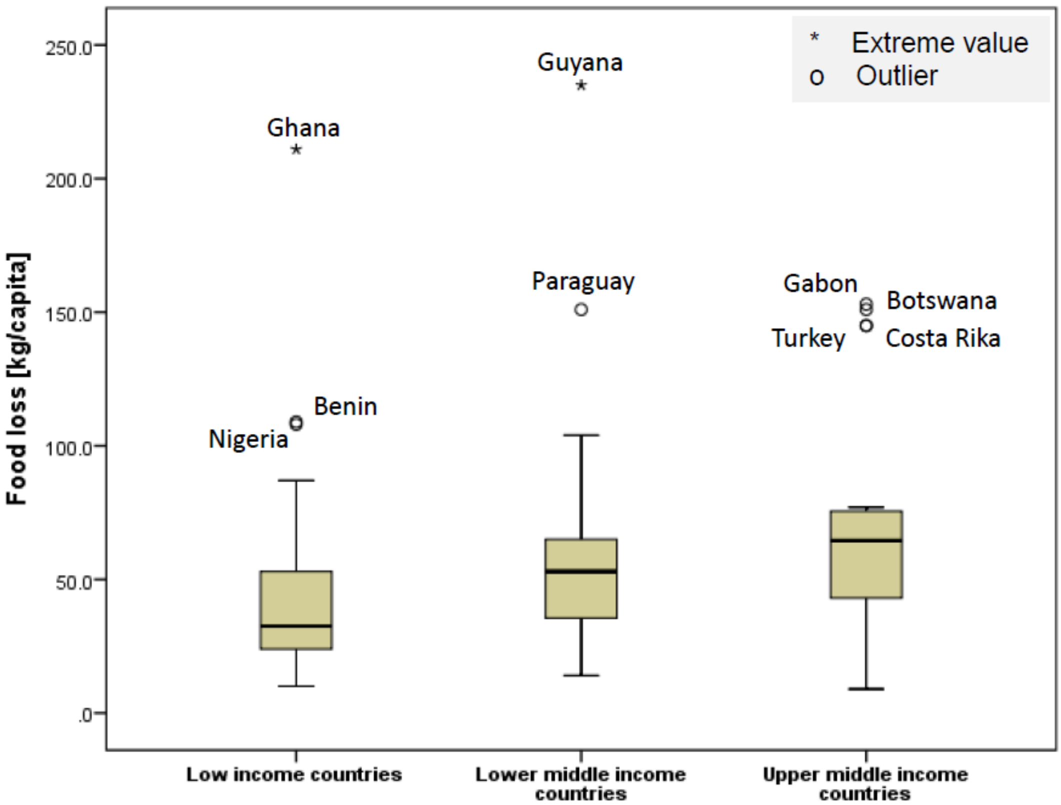

Figure 1. Box plot: countrywise average food loss/capita in each economic region, showing the countries with extremely high food loss.

3.2. Model Results

Model results show that all independent variables are highly significant in terms of explaining food loss and the model has R^2 = 0.186, which is reasonable for this type of analysis [31,32]. As expected, GDP is positively associated with food loss and the data confirm the literature by showing that richer countries lost more. The other variables all were significant and negatively associated with food loss, however, the possible impact of each variables on food loss is projected to be very different. For example, the development of the telecommunication network seems to be the strongest predictor of food loss. More specifically, our model suggests a one-unit increase in telephone density would result in a 0.20% decrease in mean food loss. By contrast, expanding road density by one kilometer of road/100 km^2 of land area would only reduce food loss by 0.06%. The effect of increasing the amount of agricultural technology seems to have a more powerful effect on food loss than increasing the road network but is less effective than increasingly the telecommunication network (see Table 2 for details).

However, this model has some limitation as it assumes a linear relationship between the amount of food loss to road and telephone densities, amount of investment in agricultural machinery, and GDP at the national level, regardless of change to other factors. For example, if a country becomes wealthier it may become more industrialized and probably less dependent on agriculture. Perhaps this may lead to less food loss, not due to the increasing of road or telephone densities but because of the reduction of agricultural activities. Similarly, one could assume the different impact of same road densities with different road qualities but the proposed model is not taking this into account. However, given that the results presented here are both intuitively logical, and conform with the literature cited above, we are reasonably confident that our approach has confirmed some important socio-technical factors that will reduce food losses if they can be addressed through policy.

Table 2. Coefficient of fixed effect multivariate regression model explaining the variability of food lost by GDP, machine value, road, and telecommunication networks. Data sources are: (1) food loss data [6]; and (2) socioeconomic data [6,33,34].

Variables	Dependent Variable (Food Loss) [1]
Gross domestic product per capita (US$) [1]	0.432 ***
	(0.0358)
Value of agricultural machinery (US$/year/100 km^2 of land area) [1]	−0.127 ***
	(0.0280)
Road density (Kilometers/100 km^2) [1]	−0.0614 *
	(0.0328)
Telephone (number of landline phones and cell phones/100 people)	−0.00206 ***
	(0.000353)
Year	0.00894 ***
	(0.00160)
Constant	−16.31 ***
	(3.076)
Observations	1526
R-squared	0.186

[1] = natural log; Standard errors in parentheses; *** $p < 0.01$, ** $p < 0.05$, * $p < 0.1$.

3.3. Scenario Analysis: The Impact of Increasing the Level of Machinery Use, Road, and Communication Networks on Food Loss Reduction

Using the model presented in the previous section, we estimated the potential effect of different scenarios aimed at reducing food loss. To do this, we calculated the amount of food that would be lost in each country if agricultural machinery, communications, and transportations systems were improved to 95% of the best performing country in that income category. This exercise resulted in three different scenarios that provide a rough order-of-magnitude assessment of how different policies might affect food loss. Overall, our analysis suggests that if all countries performed as well as the best country within their income category across these socio-economic dimensions then food loss might be decreased by about 138 million tonnes (Table 3). These results provide an illustration if policy targeted such socio-technical issues, as cell phone use and road infrastructure, there may be very significant reductions in food losses. However, that the effects of different strategies will vary from country to country (see detail in Figure 2). In terms of spatial patterns, Figure 2 shows that the largest proportional gains are likely to be found in Africa. We also observe that in addition to African countries, South Asian countries such as India, Bhutan, Nepal, and Bangladesh can reduce a significant amount of food loss by improving agricultural machinery, road, and telecommunication networks.

While we acknowledge that this analysis may provide an over-estimate of the potential for policy to reduce food losses (given the fact we were not able to account for changing marginal effects and other non-linear dynamics), it is interesting to note what variables were most important in reducing food loss. For instance, results show that investing in agricultural machinery would have greatest overall effect on food loss in determining food loss and that if all countries performed as well as the best country within the income category for the level of machinery used, then food loss in low-income countries would drop by about 42% (Table 3). In contrast, increasing road networks was the least significant factor we tested in determining food loss, particularly in low-income countries.

Table 3. Impact of machinery, road, and telecommunication improvement on food loss reduction in low, lower-middle, and upper-middle income countries. Data sources are: (1) food loss data [6]; and (2) socioeconomic data [6,33,34].

	Machinery Improvement Scenario		Road Improvement Scenario		Telecommunication Improvement Scenario	
	Δ in Food Loss (m. tonne)	%	Δ in Food Loss (m. tonne)	%	Δ in Food Loss (m. tonne)	%
Low-income countries	−17.74	42.34	−2.87	6.85	−3.08	7.35
Lower-middle-income countries	−45.15	23.80	−16.22	8.56	−36.02	18.98
Upper middle-income countries	−8.88	15.95	−5.40	9.69	−3.35	6.02
Total	**−71.77**	**24.98**	**−24.49**	**8.53**	**−42.45**	**14.78**

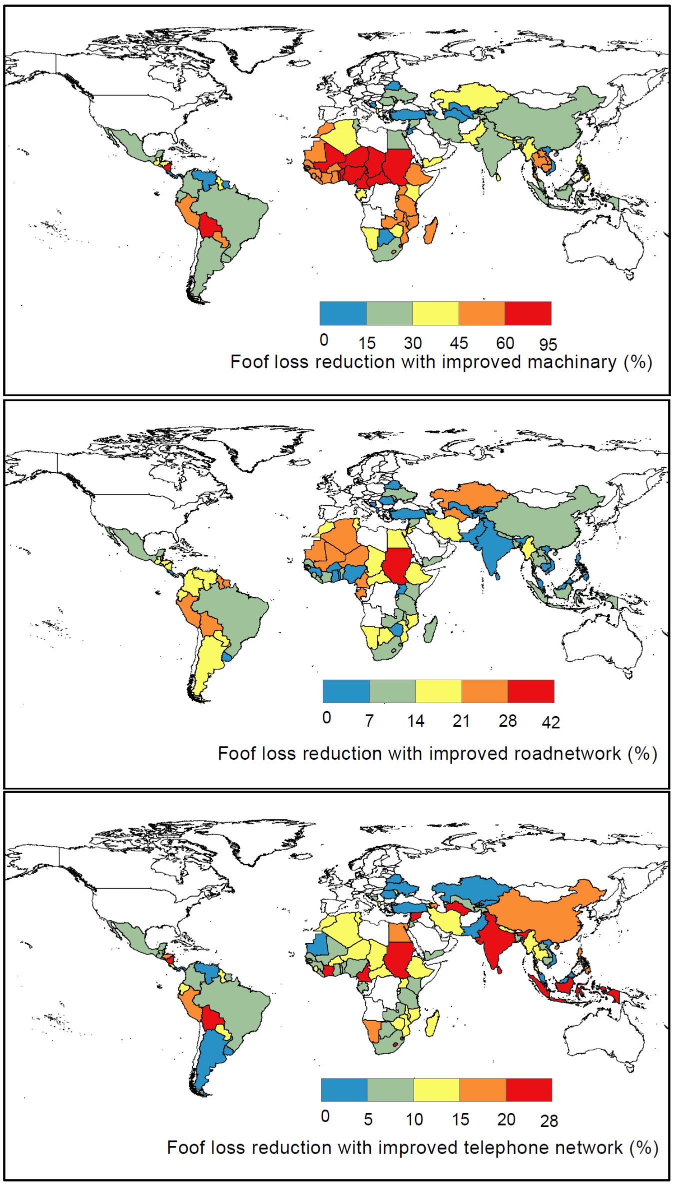

Figure 2. Modeled percentage reduction in food loss for the "improved machinery, road, and telecommunication scenario". In each scenario, we modeled the impact on food waste if all countries improved their level of all three variables to 95% of the top values within that particular income category (all lower-middle-income countries' levels of machinery, road, and telephone densities were increased to 95% of the values of the top lower-middle-income country). Data sources are: (1) food waste data [6]; and (2) socioeconomic data [6,33,34].

4. Discussion

Our analysis illustrates that the problem of food loss manifests itself differently in low-income and lower and upper middle income countries. Overall, the results presented here suggest that food loss should be addressable through policy. Our analysis shows technical fixes to the system, including improvement in machinery, roads, and telecommunications, made more of an impact in lower-income countries. Similar to Brooks et al. [21], Fraser et al. [22], and Thyberg et al. [23], through empirical analysis we were able to identify a set of factors and their relative weight of impact on reducing food loss. These factors have also been identified by other researchers working on food waste in the developing world context.

As Thi et al. [16] and Liu et al. [35] note, in developing countries, and especially in tropical regions, there is a need for more investment in improved storage, transportation, and cooling infrastructure. There is also critical need for increasing producers' access to food processing, packaging, and new markets beyond their local ones [35]. A joint FAO and World Bank report suggests that technologies and practices, such as postharvest grain management, pest management, enhanced storage structures, as well as enabling policies and institutional arrangements for grain marketing, could significantly reduce food loss in Africa [33]. For example, technologies such as small-scale rice dryers and threshers, plus new bagging techniques, which have been transferred from Asia to Africa, could make a significant difference in grain processing and storage. The spatial analyses presented above, therefore, should be seen as agreeing with these conclusions from the literature, and in particular, our results contribute to a rising consensus that Africa could particularly benefit from such technical solutions.

Technical solutions go along with an enabling environment, where government support or private sector investment in innovation (especially within "infant" industries) can be supported and encouraged. Botswana, for example, has the economic ability and the policy framework to encourage agricultural technology and innovation such as improved sorghum milling technology [33,36]. Coupled with high-tech innovations that require major public or private investment, simple, low-cost technology such as a "triple bagging" (also known as Purdue Improved Crop Storage (PICS), which is a relatively simple way of reducing post-harvest losses) has been shown to reduce food waste for cowpea and maize farmers across Sub-Saharan Africa [37]. More specifically, hermetic (airtight) PICS bags provide long-term, reliable protection against many pests without the need for chemical pesticides. Thus, this system has proven to be economically beneficial in many food systems in Africa [38,39]. Such affordable technologies could make major contributions toward addressing food loss; as Abass et al. [40] suggest, Tanzanian farmers' poor knowledge and skills regarding post-harvest management remains a major contributing factor to food losses.

Poor quality road networks present another major issue for growers, wholesalers, and retailers of food. This is especially true for people who produce/sell perishable fruits and vegetables, as they suffer significant losses due to the lack of fast and dependable transportation infrastructure to move produce to markets. As Kader [41] notes, the availability of horticultural products in most developing countries is significantly impacted by poor roads, the short supply of vehicles and other modes of transportation suited for fresh produce, all of which lead to inadequate transport of horticultural crops. For example, in Kano State, Nigeria, Olayemi et al. [42] estimate loss during transportation to be about 26% for tomatoes, 15% for bell peppers, and 10% for hot peppers. Uneven roads and the use of lorries, bicycles, or buses for transport exacerbates loss because of mechanical damage to fresh tomatoes and peppers caused by strong vibrations and impacts [42].

Communication along the food supply chain is also critical to ensure that producers know where demand is, and that retailers can adequately source and plan. Thus, addressing food loss will also entail investing in the technology necessary to transmit timely information about price trends for agricultural products in local, regional, and international markets [43]. In Honduras, for example, low-cost information and communication technology (ICT) solutions, such as SMS or text messages, have been found effective for disseminating price information to a significant portion of the Honduran population, thanks to the nation's broad cellular telephone coverage [43]. Disseminating prices over the radio presents another low-cost solution, although it is not as effective as cellular phone messages [43].

It is important to set this discussion on these local against a more global backdrop. In particular, we must recognize that that as countries achieve the efficiencies discussed above in dealing with farm-gate and postharvest losses in their food systems through technological fixes, they may not see overall reduction in food waste. This is because as countries grow rich enough to invest in this kind of infrastructure, the problem of food waste may shift away from the farm-gate and manifest itself as the kind of waste caused by consumers and retailers in the developed world. Here, it is important to reflect on the results of our statistical models that GDP is positively related to food waste. In middle-income countries, such as South Africa, although food waste from agricultural production, post-harvest handling and storage, and processing and distribution sill make up the bulk of losses along the supply chain, increasingly consumer food waste is being noted as a major problem [44–46]. Households often tend to prepare/buy too much food, especially staples such as porridge and rice, which ends up thrown away, along with expired or spoiling bread. Although the lack of proper meal planning and education around preventing food waste are major issues, marketing strategies by food retailers, such as promotional specials that are intended to clear out food items before they reach their sell-by date, has been noted to contribute to food wastage at the household level [44].

Similarly, in China, technological and infrastructural development in past decades have greatly reduced postharvest food losses; however, consumer food waste has grown due to increasing affluence and rapid urbanization [35,47]. Lui et al.'s review of food loss and waste in China estimates the food loss rate of grains in the entire supply chain to be 19.0% $\pm$ 5.8% Meanwhile, consumers are wasting 7.3% $\pm$ 4.8% [33]. It has even been estimated that food waste now constitutes 37%–62% of municipal solid waste in some Chinese cities, with catering services and restaurants accounting for a major portion of this [47,48]. For example, in Hangzhou, daily food waste production from catering services was about 1184.5 tonnes in 2010 [48]. Growing disposable income amongst contemporary Chinese seems to be eroding the traditional virtue of "cherishing food" as people now buy more food than necessary and order too much when they host guests in order to show their hospitality and wealth [35]. Given that consumers in China are responsible for a large portion of waste, awareness-raising campaigns, which have significantly increased recently in the mainstream media in China [35], could potentially redress the food waste problem. There is no doubt, however, that changing the way that people relate to their food, including shopping habits, consumption patterns, and what is thrown out, is a major challenge, but communication campaigns could influence consumer behavior and initiate change [8].

5. Conclusions

This paper began by reviewing research that shows approximately one third of the world's food is lost and demonstrated that the causes of this lost vary between the Global North (where food waste happens predominantly at the consumer and retail end of the food chain), and the Global South (where food waste is mostly a function of poor storage and marketing infrastructure). To explore this issue in more detail, we focused on the socio-economic determinants of food loss in lower, lower-middle, and middle-income countries and revealed that although GDP is positively related to food loss, investing in agricultural technologies, the transportation infrastructure and communications technologies can help reduce food loss. Overall, the results of our statistical modelling suggest that as much as 49% of this food loss could be eliminated by improvements in these factors. However, it is also important to note that food loss can also be influenced by many other factors such as access to regular energy supply, government policies and regulation and many others. Therefore, it is important to recognize the various drivers of food loss in detail and as location specific as possible. This study only provides a few determinants out of many. Such studies, supplemented with more location-specific in-depth studies, would greatly help to refine our understanding of the different drivers of food loss. In addition, we also note that as these farm-gates and marketing problems are addressed, overall food loss may not decrease. This is because as countries grow wealthy, they shift from farm-gate "food losses" to consumer and retail "food waste". As a result, while reducing food losses may be amenable to investments in infrastructure, the shift to food waste calls for more of a sociological fix than a technological one.

Supplementary Materials: The following are available online at www.mdpi.com/2071-1050/8/7/595/s1, Table S1: Summary statistics of variables, 1992–2011.

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