


## Article

# Willingness to Pay (WTP) for Heat-Tolerant Maize Hybrids in the Mid-Western Terai Region of Nepal

Atul P. Kulkarni <sup>1,\*</sup> , Mahendra P. Tripathi <sup>2</sup>, Damodar Gautam <sup>2</sup>, Keshab B. Koirala <sup>2</sup>, Manoj Kandel <sup>2</sup>, Dhruva Regmi <sup>2</sup>, Sudha Sapkota <sup>3</sup> and Pervez H. Zaidi <sup>1</sup>

<sup>1</sup> International Maize and Wheat Improvement Center (CIMMYT), Hyderabad 502324, India

<sup>2</sup> National Maize Research Program (NMRP), Rampur 44209, Chitwan, Nepal

<sup>3</sup> Nepal Agricultural Research Council (NARC), Kathmandu P.O. Box 5459, Nepal

\* Correspondence: a.kulkarni@cgiar.org

**Abstract:** High atmospheric temperatures can reduce maize production in different parts of Asia. Heat stress is the major driving force behind the need for varietal development that confers a heat tolerance trait (drought + heat tolerant) to maize hybrids. CIMMYT has developed heat-tolerant maize hybrids and deployed them in the market in collaboration with NARS partners. This study was conducted to estimate farmers' willingness to pay for heat-tolerant maize hybrids in the Terai region of Nepal. A socioeconomic survey of 404 randomly selected maize-growing households was conducted to estimate farmers' willingness to pay using the contingent valuation method. Given the economic importance of heat-tolerant maize hybrids in maize cultivation, the survey showed that the average WTP for heat-tolerant maize hybrids was 71% more than that for the current varieties in the market, including overall seed sources and subsidized seed. Without a subsidy, the farmers' WTP price was at a 19% premium compared to the average price paid for conventional hybrids. Factors such as education, owning land, the interaction of hybrid adopters and owning land, soil depth, the number of goats/sheep, and the semi-*pucca* homes of households influenced the WTP for heat-tolerant maize hybrids. Heterogeneous demand was observed with respect to years of hybrid maize cultivation, farmers' association with the network group, and the gender of the head of the household. In the context of climate change and global warming scenarios, Nepal's agriculture policy should prioritize increasing domestic seed production and the distribution of heat-tolerant maize hybrids through a public–private partnership model.

**Keywords:** heat-tolerant maize hybrid; willingness to pay; contingent valuation; preference heterogeneity; Nepal



**Citation:** Kulkarni, A.P.; Tripathi, M.P.; Gautam, D.; Koirala, K.B.; Kandel, M.; Regmi, D.; Sapkota, S.; Zaidi, P.H. Willingness to Pay (WTP) for Heat-Tolerant Maize Hybrids in the Mid-Western Terai Region of Nepal. *Sustainability* **2023**, *15*, 3068. <https://doi.org/10.3390/su15043068>

Academic Editor: Riccardo Testa

Received: 28 November 2022

Revised: 8 January 2023

Accepted: 3 February 2023

Published: 8 February 2023



**Copyright:** © 2023 by the authors. Licensee MDPI, Basel, Switzerland. This article is an open access article distributed under the terms and conditions of the Creative Commons Attribution (CC BY) license (<https://creativecommons.org/licenses/by/4.0/>).

## 1. Introduction

Population and industrial growth are the major drivers behind the global demand for rice, wheat, and maize—the world's major food staples. The world's population grew at a rate of 1.05% in 2020, with the current average increase estimated at 81 million people per year. An additional 1.2 billion people will need food by the year 2037 [1]. Optimal climatic conditions and packages of practices determine productivity in agriculture. However, climate change poses a major challenge to increasing productivity and sustaining livelihoods in the face of erratic weather patterns and scarcity of irrigation water. Drought, heat stress, and long dry periods are currently the leading causes of yield losses in South Asia, reducing crop yields by 15–20% on average in rainfed agriculture [2]. Climate-change-induced heat and water stresses are projected to drastically reduce the yields of staple crops in the region by 9–19% in maize, 44–49% in wheat, and 14% in rice [3]. While drought negatively affects all stages of crop growth and development, the reproductive stage, particularly between tassel emergence and early grain filling, is most sensitive to drought stress [4]. A study [5] hinted that in sub-Saharan Africa a 2 °C increase in temperature

would result in a greater yield loss than a 20% decrease in precipitation. Warming across South Asian countries during the twentieth and early twenty-first centuries has resulted in more frequent temperature extremes [6–8]. Heatwave frequency has increased since the mid-twentieth century in large parts of Asia [8]. The extent of heat-stressed areas in South Asia is projected to increase by up to 12% by 2030 and by 21% by 2050 with respect to the baseline [9]. Climate-smart technologies such as heat-tolerant hybrids (heat, drought, and heat + drought) are the best option to minimize the impacts of abiotic stresses.

In the 2008–2009 drought in Nepal, power outages lasted 16 h per day in Kathmandu, increasing yield losses in wheat and barley, leading to food insecurity for two million people [10]. Climate change studies conducted in the twentieth century projected that there would be water stress in most of South Asia by the year 2050 [11–13]. The average temperature is predicted to rise significantly by 0.5 °C to 2.0 °C by 2030 [14], by 1.3 °C to 3.8 °C by 2060, and by 1.8 °C to 5.8 °C by 2090 [15]. High temperatures during critical stages of crop growth, long dry spells, and high precipitation pose a risk of increased food insecurity in marginal maize-growing areas. Past experience has shown that the use of new varieties alongside improved management practices can offset yield losses by up to 40% [16]. Developing a maize germplasm with drought and heat tolerance is seen as the right step toward risk mitigation in hotter and drier production environments. The drought tolerance trait in maize has global value, without which no farmer can afford it [17,18], given the climate change scenario. The current rate of water use is not sustainable if the world is to support 9 billion people or more in 2050 [19].

The International Maize and Wheat Improvement Center (CIMMYT), together with its national partners, has developed climate-smart technologies such as drought- and heat-tolerant maize hybrids (Rampur Hybrid-10 (RH-10) and Rampur Hybrid-8 (RH-8)) to minimize the effects of climate change. The adoption of these improved hybrids is governed by farmers' willingness to pay for their traits. The best way to assess the effective demand for drought- and heat-tolerant traits is to quantify the implicit price of the desired traits. This study was designed to estimate the farmers' WTP for such traits and facilitate the scaling of drought- and heat-tolerant maize technology in the Terai region of Nepal.

## 2. Relevance of Heat-Tolerant Maize in Nepal

Nepal is a topographically diverse country, with mountains covering 35%, hills covering 42%, and the Terai region covering 23% of its total area. Given the country's extreme topography, only 21% of its total land area is suitable for agriculture. Of the total agricultural land, 29.7% is irrigated [20]. Nepal's principal economic activity is agriculture, which contributed 30.7% of its GDP in 2019–2020. Maize is the second most important cereal crop grown for food, feed, and fodder [21], which showed an increase in production of 0.279 million tons and a 0.37% increase in area (3492 ha) in 2019–2020 compared to the 2017–2018 production of 2.56 million tons from a 0.95-million-hectare area [22]. In the 2020/2021 fiscal year area, production, and productivity were estimated to have increased by 0.21%, 3.22%, and 3%, respectively, compared to 2019/2020 [23]. Maize provides livelihoods (income and employment) to around 1.5 million people [24]. The per capita maize consumption in Nepal was 98 g/person/day [25]. Demand for the crop has grown by about 5% per year over the last few decades [26]. About 16.42% of the maize is grown in the Terai and inner Terai regions [27]. The crop contributes 25.4% of the total edible production in the country [28]. Nonetheless, 51.8% and 25.2% of households in the country are food insecure and under the poverty line, respectively [29].

Of the total area under maize in Nepal, summer maize contributes 73.9%, spring maize contributes 14.2%, and winter maize contributes 11.9% [23]. Around 88% of the maize area (summer- and spring-grown) is susceptible to heat stress at both the vegetative and reproductive stages, particularly during pollination and grain setting. Yield losses of up to 75% have been reported due to heat stress [30], depending on crop stage, severity, and duration of stress [31]. High temperatures above 38 °C at the time of silking and

anthesis have led to leaf firing and tassel blast, which led to poor pollination and barren ears, resulting in yield loss.

Shallow tube wells are the major source of irrigation in Banke district. Most farmers with shallow tube wells used 0.5 hp motors to irrigate their maize fields, making it a time-consuming process. Decreasing water levels in the summer season are a major cause of unequal water distribution and insufficient irrigation.

According to an estimate, only 12–15% of the maize area in Nepal is under hybrid cultivation, and 85–88% is under open-pollinated varieties (OPV)s [32], a major cause of low productivity. The demand for feed has been increasing at the rate of 11% per year [33]. The demand for poultry feed is estimated to be 391,538 metric tons, with 75% of this amount fulfilled through imports. Over a 20-year period (1994/1995 to 2014/2015), the country's livestock population increased by 0.73 to 1.23% annually [34].

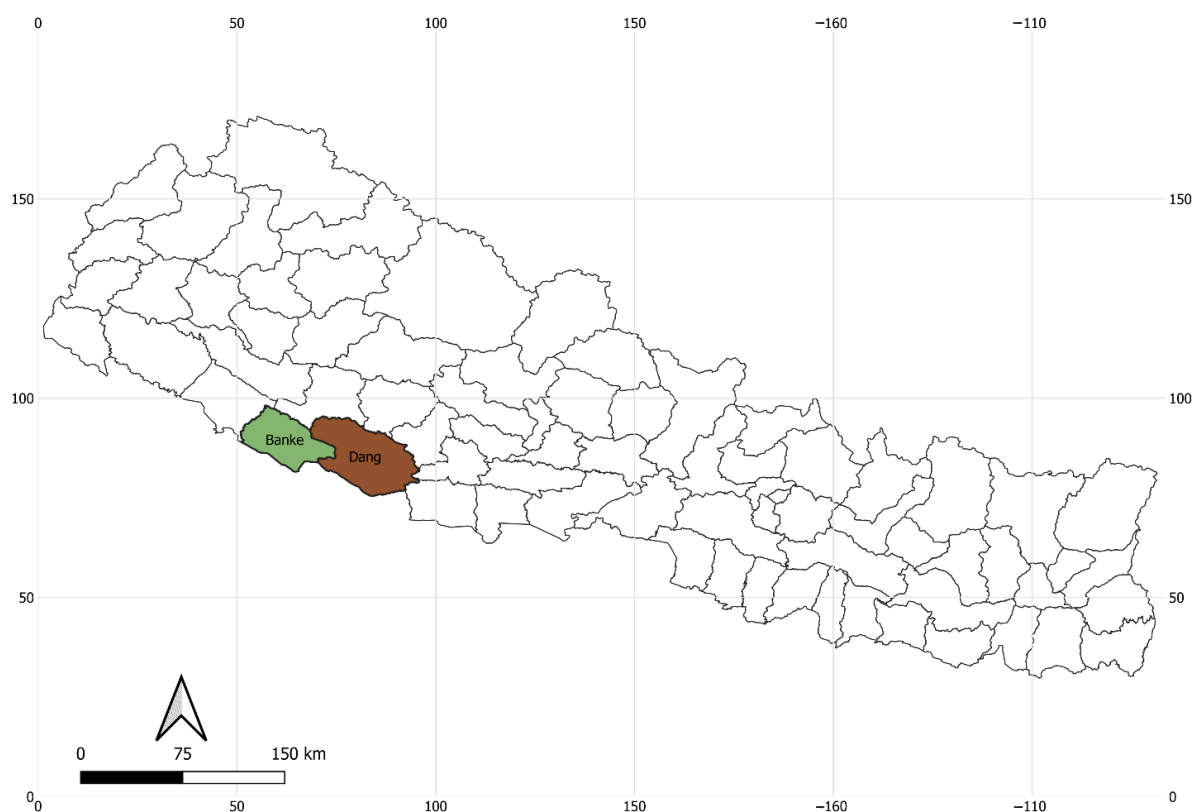
Considering maize's diverse uses, demand for it will keep growing. To meet the internal demand, Nepal imported 0.4 million tons, valued at USD 115.94 million, in 2019–2020. Since Nepal's national hybrid seed system is in the early stages of development, the country relies heavily on imported hybrid maize seeds, whose demand expanded from 20 tons in 2008 [35] to 27,754 tons in 2019–2020 [22]. These imports created a trade deficit of USD 9.7 million from the maize seed sector alone.

Open-pollinated varieties have some limitations in terms of yield potential. Their yields cannot be increased beyond a point, even with high inputs. On the contrary, a hybrid can give 25–30% higher grain yield compared to OPVs [23]. However, the limited choice of hybrids, poor access to improved seeds of released or registered hybrids developed by the national system, and the high seed price of imported hybrid seeds could be some reasons for the low adoption of hybrid seeds. Research in hybrid maize in Nepal started in 1987 to increase production and productivity. Since then, the country has released 29 OPVs and 10 hybrids (years in parentheses): Gaurav (2003), Rampur Hybrid-2 (2012), Khumal Hybrid-2 (2014), Rampur Hybrid-4 (2016), Rampur Hybrid-6 (2016), Rampur Hybrid-8 (2018), Rampur Hybrid-10 (2018), Rampur Hybrid-12, Rampur Hybrid-14, and Rampur Hybrid-16 (2022). Of these, Rampur Hybrid-8, Rampur Hybrid-10, and Rampur Hybrid-12 are heat-tolerant single-cross hybrids developed under the HTMA/CIMMYT project funded by USAID. Along with these, multinational companies developed 53 hybrids registered for marketing in the country [23].

### 3. Materials and Methods

#### 3.1. Data

This study is based on primary household surveys conducted in the Banke and Dang districts in the Terai region of Nepal in August 2021. Face-to-face interviews with household heads were conducted, and data were collected using a structured questionnaire that was designed using an electronic software (Kobo collect toolbox, v2021. 2.4) to minimize data entry errors and survey time. The districts were selected purposively on the basis of the deployment of Rampur Hybrid-10 by seed companies in the maize super zone, large maize areas under cultivation, and spring maize areas and the potential for the adoption of a heat-tolerant maize hybrid in Nepal. The location of the study districts is shown in Figure 1. The total area under maize in Dang district was 26,250 ha, with 75,081 tons of production, whereas the corresponding figures for Banke district were 9336 ha and 25,913 tons in 2019–2020 [22].



**Figure 1.** Location of the study area in Nepal.

### Sampling Technique

The total population of both surveyed districts was 1,043,896 (Dang: 552,583 [36] and Banke: 491,313) [36], as per the 2011 census of Nepal. The sample size ( $n$ ) of 400 was estimated using the formula by Yamane [37], as shown in Equation (1).

$$n = \frac{N}{1 + N(e)^2} \quad (1)$$

where  $N$  = total population and  $n$  = sample size.

$$n = \frac{1,043,896}{1 + 1,043,896(0.05)^2}$$

$$n = 400$$

As RH-10 is a recently released hybrid, the seed was distributed through the super zone for maize and co-operative societies. A list of adopters was collected from the super zone and co-operative societies to select adopters. A list of maize farmers was collected from rural municipalities to randomly select non-adopter farmers. Based on the deployment of seed in the super zone for maize, Rapti, Gadawa, and Rajpur rural municipalities and Lamahi municipality were purposively selected from Dang district, and Khajura and Duduwa rural municipalities were selected from Banke district. In total, 25 villages were selected: 6, 5, 1, and 4 from Rapti, Gadawa, Rajpur, and Lamahi municipalities, respectively, and 1 and 8 from Duduwa and Khajura municipalities, respectively. From each village, 16–18 farmers (8–9 adopters and 8–9 non-adopters) were randomly selected from the list. Of the total surveyed households, 192 farmers had adopted the heat-tolerant maize hybrid Rampur Hybrid-10 and 212 were growers of conventional maize varieties. Among the farmers, 357 were adopters of the maize hybrid and 47 were growers of OPVs or local varieties. Finally, a pool of 404 households (258 in Dang and 146 in Banke) was randomly selected

for the survey to ascertain farmers' WTP for Rampur Hybrid-10, which is a heat-tolerant maize hybrid.

### 3.2. Analytical Framework

The contingent valuation method originally developed in environmental and natural resource economics was employed to elicit farmers' demand for heat-tolerant maize hybrids [38]. The WTP can be estimated either using open-ended questions, such as asking respondents the maximum amount they are willing to pay, or through closed-ended questions, such as if they would be willing to pay a specific amount (dichotomous choice). This study used the dichotomous choice (DC) approach, which is generally superior to an open-ended format, as it confronts respondents with a more market-like situation [39]. In the single-bound model, farmers can provide a "yes" or "no" response to the initial bid offered for the technology. This approach is incentive-compatible; it is in the strategic interest of respondents to say "yes" if their WTP is greater than or equal to the price asked and "no" otherwise [38]. Utility maximization implies that respondents will only answer "yes" to the offered bid if their maximum WTP is greater than the bid. However, the single-bounded model requires a large sample and is statistically inefficient [40]. Greater efficiency is achieved in the double-bound model by offering respondents a second bid that is higher or lower, depending on the first response. This method incorporates more information about an individual's WTP and therefore provides more efficient estimates and tighter confidence intervals [40]. The double-bounded model is easy to administer, and the model can be estimated with standard econometric software, so we used a double-bounded model in our study.

In the DC approach, the consumer is presented with two consecutive bids, and the second bid depends on the response to the first. If the consumer answers "yes" to the first bid ( $B_i$ ), the second bid ( $B_i^u$ ) is set higher, but if the individual responds "no" to the first bid, the second bid ( $B_i^d$ ) is set lower. There are four possible outcomes: "yes" to the first bid followed by a "yes" to the second bid (with a probability denoted by  $P^{yy}$ ); "yes" followed by "no" ( $P^{yn}$ ); "no" followed by "yes" ( $P^{ny}$ ); and two consecutive "no" answers ( $P^{nn}$ ). The price bids varied randomly across the questionnaire, ranging from Nepalese rupee (NPR) 300/kg to NPR 700/kg based on the seed prices of different brands and seed subsidies provided by the Nepalese government. The format of the WTP questionnaire is given in Appendix A. To obtain information on a wide range of values, different bid amounts were randomly assigned between respondents ( $i$ ). Combining the probabilities of the four outcomes, the log-likelihood function for this model for a sample of  $n$  consumers takes the form:

$$\ln L = \sum_{i=1}^N d^{YY} \ln \left[ 1 - \Phi \left( \frac{B^u - \beta'x}{\sigma} \right) \right] + d^{YN} \ln \left[ 1 - \Phi \left( \frac{B^u - \beta'x}{\sigma} \right) - \Phi \left( \frac{B_i - \beta'x}{\sigma} \right) \right] + d^{NY} \ln \left[ 1 - \Phi \left( \frac{B_i - \beta'x}{\sigma} \right) - \Phi \left( \frac{B^d - \beta'x}{\sigma} \right) \right] + d^{NN} \ln \left[ \Phi \left( \frac{B^d - \beta'x}{\sigma} \right) \right] \quad (2)$$

where  $B_i$  is the initial bid;  $B^u$  is the follow-up bid;  $B^d$  is the lower bid; and  $d^{YY}$ ,  $d^{YN}$ ,  $d^{NY}$ , and  $d^{NN}$  are binary variables, with 1 denoting the occurrence of that particular outcome and 0 otherwise. The parameter  $\sigma$  is the standard error of the regression, which captures the randomness in the bid function. The estimation coefficient ( $\beta$ ) can be directly interpreted as the marginal effect of the variable  $x$  on WTP. The mean WTP was obtained by evaluating the estimated coefficient at the variables' mean values.

## 4. Results and Discussion

### 4.1. Multilocation Trials of Heat-Tolerant Maize Hybrid

A multilocation evaluation trial (MLT) of Rampur Hybrid-10 on a 10 m<sup>2</sup> plot with other hybrid cultivars as checks was conducted by CIMMYT to compare their performance in the 2017–2018 spring season (Table 1). The potential grain yields per plot of all the hybrids were recorded and converted to tons/ha at a standard moisture of 12.5%. The trials were

conducted under high input and stressful environmental (spring season) conditions. The minimum yield was 4.52 t/ha in Bittipara, and the maximum was 8.25 t/ha in Nepalgunj I. In Bittipara, the performance of Rampur Hybrid-10 was significantly superior to that of commercial check 1 and on par with those of the other checks. In Sherpur, Rampur Hybrid-10 performed significantly better than the regional check, commercial check 1, and commercial check 2 and on par with commercial check 3. In Nepalgunj I and II, Rampur Hybrid-10's performance was superior to those of the regional check and commercial check 1 and on par with those of the other checks. Among the trials in the six locations, Rampur Hybrid-10's performance was superior to the regional or commercial checks in four locations and on par with them in two locations in the spring season. High temperatures/heat waves coinciding with the flowering/reproductive stage adversely affected pollen viability and stigma receptivity, leading to abnormal fertilization and resulting in poor grain setting. Given that uncertain climatic conditions and the probability of long dry spells and high temperatures/heat are higher in rainfed agriculture, the adoption of a heat-tolerant hybrid is a strategic way to minimize yield losses that occur due to heat stress.

**Table 1.** Potential grain yields (t/ha) of heat-stress-tolerant maize hybrids, demonstrated in multilocation trials in Nepal in the 2017/18 spring season.

Entries/Location	Bittipara	Sherpur	Rampur	Nepalgunj I	Nepalgunj II	Siraha	Mean Yield across Locations [SD] ×
Rampur Hybrid-10	4.52	5.68	6.75	8.25	5.02	6.83	6.17 [1.37]
Regional Check	3.87 (0.65)	4.76 (0.92) **	5.94 (0.81)	5.46 (2.79) **	3.00 (2.02) **	7.29 (−0.46)	5.05 [1.53]
Commercial Check 1	3.21 (1.31) **	4.69 (0.99) **	7.89 (−1.14)	6.13 (2.79) **	2.23 (2.79) **	7.57 (−0.74)	5.29 [2.31]
Commercial Check 2	4.38 (0.14)	4.63 (1.05) **	5.49 (1.26)	8.04 (0.21)	3.52 (1.50)	7.23 (−0.4)	5.55 [1.75]
Commercial Check 3	4.09 (0.43)	4.99 (0.69)	6.86 (−0.11)	8.85 (−0.75)	5.77 (−0.75)	6.58 (0.25)	6.19 [1.66]
Mean yield (t/ha)	4.06	4.66	6.18	7.90	4.65	7.08	-
SD (location yield)	0.63	0.71	0.87	1.07	0.96	0.49	-
Least Significant Difference (LSD@0.05)	1.21	0.77	1.65	1.53	1.88	1.11	-
Number of entries (observations)	25	25	25	25	25	25	-

\*\* = statistically significant at 5% level. SD = standard deviation. × = Figures in [] indicate the standard deviation across locations. Note: Figures in parentheses indicate the differences between the yield of Rampur Hybrid-10 and the respective checks. If the difference is more than the LSD value, then Rampur Hybrid-10 is significantly superior to the respective check.

#### 4.2. Socioeconomic Characteristics of Farmers

The socioeconomic profile of the sampled households is presented in Table 2. Of the surveyed households, 92% were male-headed. The average age of the household heads was 50.53 years. Most of the respondents (58.42%) were aged between 41 and 60 years, followed by 21.29% being less than 40 years old and 20.23% being more than 61 years old. Significant differences were observed among adopters and non-adopters of the heat-tolerant hybrid. The education status of the household head was found to be at a secondary level. Adivasi/Janajati respondents constituted 58% of the sample households, whereas 30% of them were Brahmin/Chhatri. About 86% of the households were members of social networks such as agricultural co-operative societies and self-help groups, which allowed them direct access to schemes/programs implemented by the Nepal government to promote cutting-edge technology. The average size of the owned land was 0.92 ha. About 73.27% of the households had land holdings that were below 1 ha, 19.55% had land holdings between 1.01 ha and 2 ha, 4.95% had land holdings between 2.1 ha and 4 ha, and only 2.23% had had land holdings of more than 4.1 ha. The per capita land holding size was only 0.15 ha. Of their own land, 0.27 ha was allocated to maize cultivation. Given the

open border between India and Nepal, farmers in adjoining districts have been cultivating hybrid maize since 1980. On average, farmers have been cultivating hybrid maize for the last 3.5 years in the study locations. The mass adoption of hybrid maize varieties began 5–6 years ago in Dang district and in the last 2–3 years in Bankej district. Significant differences were observed among adopters and non-adopters of heat-tolerant hybrids in terms of the distances to input dealers and extension offices. The Nepalese government has been promoting different schemes to promote the swift adoption of hybrid maize.

**Table 2.** Socioeconomic profile of the surveyed farmer households.

Variables	Overall (n = 404)			Adopters (n = 192)			Non-Adopters (n = 212)			Mean Difference
	Mean	SD	Median	Mean	SD	Median	Mean	SD	Median	
Gender of household head (male = 1)	0.92	0.28	1	0.92	0.28	1	0.92	0.28	1	0.00
Age (years)	50.53	11.84	49	51.93	11.76	52	49.27	11.8	48	2.66 **
Education (years)	6.71	4.59	8	6.86	4.65	8	6.58	4.53	8	0.28
Household members	6.86	3.8	6	7.03	3.78	6	6.71	3.82	6	0.32
Caste dummy 1 (Adivasi/Janajati = 1)	0.58	0.49	1	0.58	0.49	1	0.59	0.49	1	0.00
Caste dummy 2 (Brahmin/Chhatri = 1)	0.3	0.46	0	0.33	0.47	0	0.27	0.44	0	0.06
Member of any group	0.86	0.35	1	0.93	0.26	1	0.79	0.41	1	0.14 ***
Owned land (ha)	0.92	0.99	0.63	1.05	1.12	0.67	0.81	0.84	0.53	0.24
Maize plot (ha)	0.27	0.26	0.2	0.26	0.25	0.17	0.27	0.26	0.2	−0.01
Years of maize hybrid cultivation	3.5	2.63	3	3.54	2.04	3	3.48	3.06	3	0.06
Distance to input dealer (km)	3.18	3.82	2	2.83	3.87	2	3.49	3.76	2	−0.66 *
Distance to extension offices (km)	6.39	4.25	5	6.01	4.33	5	6.73	4.12	6	−0.72 *
Household member migration (No.)	0.51	0.76	0	0.5	0.69	0	0.53	0.81	0	−0.03
Off-farm income ('1000 NPR)	254.74	475.92	120	275.01	521.55	150	236.38	430.89	116	38.63
Female buffaloes (No.)	0.95	1.79	1	0.92	1.64	1	0.98	1.92	1	−0.06
Goats/sheep (No.)	4.4	4	4	4.72	4.36	4	4.09	3.64	4	0.63
Soil depth (cm)	31.53	9.03	30	32.41	9.27	30	30.75	8.76	30	1.66 *
Male workers in household (No.)	2.13	1.43	2	2.2	1.48	2	2.08	1.39	2	0.12
Female workers in household (No.)	2.17	1.35	2	2.21	1.32	2	2.12	1.36	2	0.09
Maize grown in spring season	0.59	0.49	1	0.66	0.47	1	0.53	0.5	1	0.13 ***
Pucca house	0.7	0.46	1	0.7	0.46	1	0.7	0.46	1	0.00
Semi-pucca house	0.18	0.39	0	0.23	0.42	0	0.14	0.35	0	0.09 **
Kutch house	0.12	0.32	0	0.07	0.26	0	0.16	0.36	0	−0.08 ***
District (Dang = 1)	0.64	0.48	0	0.63	0.48	0	0.65	0.48	0	−0.02

\*\*\*, \*\*, \* = statistically significant at 1%, 5%, and 10% levels, respectively; No. = number. Exchange rate: USD 1 = NPR 118.13 [41]

Agriculture remains the major source of occupation, providing employment to 77.48% of the households in the study location. Low land size and over-dependency on agriculture has led to outmigration. Of the surveyed households, 207 members (0.51%) had outmigrated from 158 households (39%). Of the total number that had migrated, 51.21% had migrated within Nepal, 32.85% had migrated to other countries (Qatar, Saudi Arabia, Dubai, etc.), and 15.94% were taking part in seasonal migration to India. The major reported reasons for migration included low per capita land holding, the non-availability of employment in the village, and greater possible earnings outside Nepal than within the country, among other factors. Off-farm income was calculated by taking into account salary, business, machinery earnings, migration, and other sources and was estimated to be NPR 254,740/year. Income from remittance was not considered to calculate off-farm income. A buffalo and 4–5 sheep/goats were held by each household. The average soil depth in an adopter farmer's maize plot was 32.41 cm, significantly different from that in a non-adopter's plot (30.75 cm). About 59% of the households grew maize in the spring season, whereas 36% grew it in the winter season, indicating their clear preference for spring season cultivation. As a result of income received from remittances and migration income, 70% of the households had *pucca* houses on their own farm and 18% had semi-*pucca* houses, of which 23% of households adopted a new hybrid while 14% grew conventional maize varieties.

#### 4.3. Economics of Maize Production in Nepal

The detailed cost of maize cultivation by farmers is given in Table 3. The average paid-out cost was NPR 38,170/ha; adopter households had a significantly (at the 5% level) lower paid-out cost of NPR 36,060/ha than the non-adopters, with NPR 40,090/ha. The significant

difference in paid-out cost was because of the seed cost. A detailed breakdown of the cost of cultivating maize is given in the Supplementary Materials (Table S1). The average seed rate used by farmers was 22.59 kg, which cost around NPR 7350/ha. Adopter farmers reported an average seed cost of NPR 5370 of Rampur Hybrid-10, which was significantly lower (at the 1% level), by NPR 3790, than that reported by non-adopters, with a seed cost of NPR 9150/ha. Hybrid seed is subsidized by 50% if purchased from the government's Prime Minister Agriculture Modernization Project (PMAMP) maize super zone, whereas there is no subsidy if purchased from dealers. Rampur Hybrid-10 is produced and marketed by private seed companies in Nepal, and other conventional maize hybrids are imported from neighboring countries such as India, which includes the cost of transportation, import taxes, and storage charges, which increase the seed cost. In-country (Nepal) hybrid seed production, which reduces over-dependency on other countries and boosts the local seed industry, has been one of the major achievements of the HTMA project funded by USAID. Agricultural universities recommend fertilizer application for maize at 180:60:60 NPK/ha, which requires them to apply 340 kg of urea/ha, 130 kg of DAP/ha and 67 kg of potash/ha. Farmers, on the other hand, used very little fertilizer, which could be one of the reasons for low productivity. There is a scope for the use of optimal fertilizer doses to increase productivity per unit area. Very few farmers use micronutrients or weedicides. The total cost, including family labor, was estimated to be NPR 77,390/ha. Most of the farm work was being performed by family members, as the average family size was 6.86 members. Hence, expenses for hired labor were very low. A study in 2022 [35] estimated that the total variable cost of hybrid maize adopters was NPR 74,299/ha, which is similar to our findings. Households that adopted Rampur Hybrid-10 reported an additional yield of 0.36 tons/ha and an additional net income of NPR 13,720/ha compared to conventional maize growers. Studies revealed that stress-tolerant varieties provide higher and stable yields during dry spells and serve as a risk management strategy in the absence of institutional insurance mechanisms [42–44].

**Table 3.** The economics of maize production in Nepal.

Variables	Expenses and Revenue ('1000 NPR/ha)						Mean Difference
	Overall		Adopters		Non-Adopters		
	Mean	SD	Mean	SD	Mean	SD	
Paid-out cost	38.17	16.3	36.06	14.01	40.09	17.95	−4.03 **
Family labor cost	39.22	15.38	40.34	15.84	38.20	14.93	2.14
Total cost, with imputed value of family labor	77.39	18.71	76.40	18.02	78.29	19.31	−1.89
Maize grain yield (tons)	4.24	1.61	4.42	1.35	4.06	1.80	0.362 **
Price received ('1000 NPR /ton)	27.33	3.59	27.41	3.410	27.25	3.75	0.16
Grain income	115.88	44.79	121.15	38.53	110.64	49.30	11.01 **
Dry fodder value	11.93	4.28	12.36	3.65	11.54	4.75	0.82 *
Gross income	127.81	48.55	133.51	41.48	122.18	53.64	11.83 **
Net income	50.42	45.97	57.11	42.53	43.89	48.05	13.72 ***

Note: number of observations = 404. \*\*\*, \*\*, \* = statistically significant at 1%, 5%, and 10% levels, respectively. Exchange rate: USD 1 = NPR 118.13 [41].

#### 4.4. Respondents' Willingness to Adopt Heat-Tolerant Maize Hybrids

The initial bids offered to the surveyed farmers are given in Table 4. The bids ranged from NPR 300 to NPR 700 in NPR 50 intervals. Bids were decided following discussions with dealers and distributors and were based on the current prices of hybrids in the country's market. Of the surveyed farmers, 357 grew hybrid maize varieties and 47 farmers grew OPVs. Overall, 61% of the farmers were willing to adopt heat-tolerant maize hybrids at the given seed prices. While 65% of the adopters of maize hybrids were willing to adopt heat-tolerant maize hybrids, only 28% of the non-adopters (farmers growing OPVs)

were willing to adopt heat-tolerant hybrids. Moreover, adopters of hybrid maize were willing to pay a greater price for heat-tolerant hybrids compared to non-adopters. It was observed that as the bid price increased, the willingness to adopt heat-tolerant hybrids decreased, indicating that the bid prices mentioned in the study suited the hybrid seed market in Nepal.

**Table 4.** Respondents' willingness to adopt heat-tolerant maize hybrids.

Initial Bid (Seed Price in NPR)	Number of Respondents That Faced the Bid Amount			Share of Respondents Willing (Yes = 1) to Adopt Heat-Tolerant Hybrids at the Elicited Seed Price		
	Hybrid Maize Adopters	Non-Adopters	Overall	Hybrid Maize Adopters	Non-Adopters	Overall
300	34	1	35	0.88	1.00	0.89
350	28	4	32	0.86	0.50	0.81
400	46	4	50	0.78	0.25	0.74
450	54	10	64	0.78	0.30	0.70
500	64	4	68	0.73	0.50	0.72
550	47	5	52	0.62	0.20	0.58
600	24	5	29	0.38	0.00	0.31
650	28	10	38	0.39	0.30	0.37
700	32	4	36	0.13	0.00	0.11
Overall	357	47	404	0.65	0.28	0.61

Pearson's chi2 statistic for the association between the adoption of hybrid maize and the willingness (yes = 1) to adopt heat-tolerant hybrids was 24.25, which was statistically significant at  $p < 0.01$ .

#### 4.5. Factors Influencing Farmers' Willingness to Pay for Heat-Tolerant Maize Hybrids

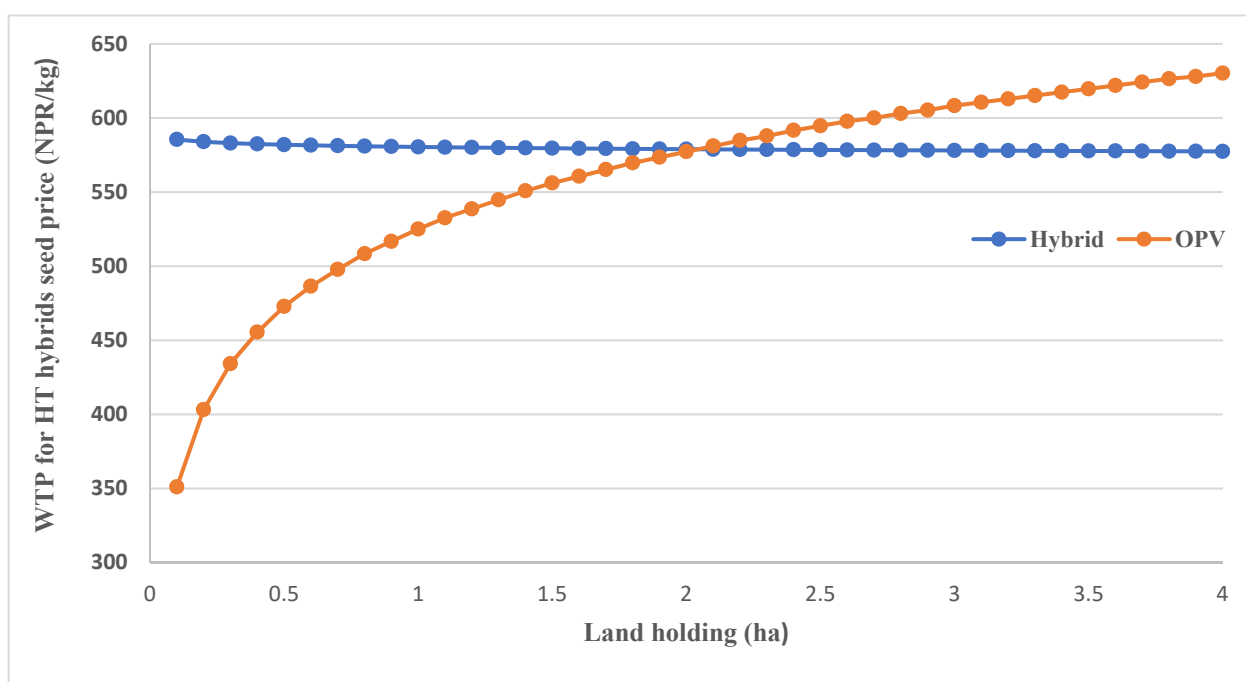
We estimated two WTP models. Model 1 consisted of socioeconomic characteristics, while model 2 included the interaction of hybrid adopters with their own land (log) and the interaction of household membership in a group with hybrid adopters (Table 5). The results from the two models were fairly consistent with respect to significance, except for hybrid adopters and interactions. It was observed that increasing the education level by one year played a positive role in influencing WTP for a heat-tolerant maize hybrid compared to illiterate farmers. In Kenya, Kimunji and Groote [45] observed that people with secondary schooling showed a significantly higher WTP for genetically modified food than those with either less or more education. In model 1, hybrid maize adopters were willing to pay a significantly higher price for heat-tolerant hybrids compared to those who grew OPVs. This was because hybrid adopters knew the comparative yield advantage of hybrids over OPVs and were therefore willing to pay a premium price for heat-tolerant maize hybrids. Model 2 showed that increasing owned land played a vital role in influencing the WTP for heat-tolerant hybrids. Farm size and education were shown to significantly influence the WTP for *Bt* eggplant in India [46]. The owned land/farm size results were similar to those in earlier studies showing that farm size is an important determinant of the adoption of the latest technologies in developing countries [47–49]. The interaction of hybrid adopters and owned land was significant but negatively influenced the WTP for heat-tolerant hybrids. This is clearly explained in Figure 2. Figure 2 shows the prediction of WTP for heat-tolerant hybrids among hybrid adopters and OPV farmers. If OPV farmers adopt heat-tolerant hybrids, their WTP increases with increasing land holdings, whereas the WTP of hybrid adopters is similar irrespective of land holding. This indicates that in order to promote heat-tolerant maize hybrids, extension agents should focus on OPV farmers rather than hybrid adopters. The interaction of member groups and hybrid adopters showed a positive association that did not significantly influence WTP.

Livestock rearing is complementary to agriculture. Farmers feed maize grain as a concentrate to sheep/goats to increase their weight and obtain a better price. Farmers consider sheep/goats to be a liquid asset that can be sold in any emergency. The availability of stable feed and fodder in a stressful environment is made possible by the adoption of a heat-tolerant maize hybrid.

**Table 5.** Determinants of farmer demand for heat-tolerant maize hybrids: interval regression estimates.

Variables	Model 1		Model 2	
	Coefficient	Robust SE	Coefficient	Robust SE
Sex of household head (male = 1)	54.25	35.85	54.38	35.99
Age (years)	−1.08	0.93	−1.11	0.92
Caste (Brahmin/Chhatri = 1)	0.20	26.35	0.93	26.24
Education (years in school)	4.71 **	2.32	5.15 **	2.32
Group membership	39.29	26.24	72.26	55.75
Maize plot (ha; log-transformed)	11.78	13.14	13.39	13.07
Hybrid adopter (adopter = 1)	126.68 ***	29.14	84.57	52.05
Owned land (ha; log-transformed)	−20.45 *	12.08	62.33 **	32.63
Hybrid adopters # owned land (interaction)	−	−	−90.02 **	32.51
Group membership # hybrid adopters (interaction)	−	−	−45.33	62.75
Distance to input dealer (km)	−0.66	2.91	−0.58	2.91
Distance to extension offices (km)	0.20	2.52	0.14	2.51
Household member migration (No.)	−3.46	10.69	−1.36	10.64
Off-farm income (NPR)	0.00	0.00	0.00	0.00
Female buffaloes (No.)	1.14	5.64	1.01	5.60
Goats/sheep (No.)	6.43 **	2.38	6.39 **	2.38
Soil depth (cm)	3.82 ***	1.19	4.12 ***	1.20
Male workers in household (No.)	11.95	9.97	12.43	9.99
Female workers in household (No.)	−0.23	9.05	−0.28	8.94
Spring season (yes = 1)	38.28 *	19.92	39.32 **	19.70
Semi-pucca house	50.26 **	25.01	54.67 **	25.30
Kutcha house	10.99	32.45	10.06	32.25
District (Dang = 1)	−2.36	26.28	−2.84	26.07
Model intercept	196.95	85.37	235.65	86.84
Sigma	145.57 ***	8.09	144.41 ***	8.10
Log-pseudolikelihood	−421.95	−	−418.70	−
Wald chi2 statistics	91.79 ***	−	100.10 ***	−
Number of observations	404	−	404	−

\*\*\*, \*\*, \* = statistically significant at 1%, 5%, and 10% levels, respectively. SE = standard error. # interaction.



**Figure 2.** Prediction of willingness to pay (WTP) for heat-tolerant hybrids among hybrid and OPV adopters with respect to land holdings.

A farmer with sheep/goats was significantly more willing to pay an additional price for a heat-tolerant variety compared to a farmer with no sheep/goats. Soil depth indicates the quality of soil and fertility. Farmers with plots with good soil depth/quality were willing to pay more for Rampur Hybrid-10 compared to maize growers with poor soil quality. Male farmers were mostly the decision makers on the type of variety to be grown (local/improved/hybrid) and the price to pay for it. The exposure of male farmers to extension sources was greater compared to women. As a result, more male workers in households were willing to pay a premium price for the heat-tolerant trait than female workers but with no significant difference. With respect to season, farmers growing maize in the spring season were significantly more WTP a premium price for heat-tolerant hybrids compared to those who grew winter-season maize. In the spring season, farmers planted maize after harvesting mustard or potatoes. Increased irrigation sources and facilities enable farmers to grow three crops in a year. Spring- and summer-season maize are more exposed to heat stress, with up to 75% yield losses reported due to heat stress [30]. It is projected that heat-tolerant maize varieties could minimize yield losses from current maize varieties by up to 36% and 93% in 2030 and by up to 33% and 86% in 2050 under rainfed and irrigated conditions, respectively [9]. The type of household positively and significantly influenced the WTP for heat-tolerant maize hybrids. Farmers living in semi-pucca homes were ready to pay the premium price compared to farmers in *pucca* houses. The major source of income of farmers in semi-*pucca* houses was agriculture, and for those in *pucca* houses, remittances and off-farm income contributed the major source of income.

#### 4.6. Mean WTP for Heat-Tolerant Hybrids and the Relationship between Land Ownership and Hybrid Adoption

The mean WTP for heat-tolerant maize hybrids across land holdings and the type of variety grown is presented in Table 6. The results are based on the prediction from the WTP interval regression model, as specified in Table 5 (model 2). The result shows that the mean WTP for heat-tolerant maize hybrids was NPR 557.57/kg (USD 4.72), and this amount is 71.37% more than the current average seed cost of NPR 325.36 (USD 2.77)/kg, considering overall seed sources, including subsidized seed. The average price paid by farmers for maize seed without subsidy was NPR 470.06/kg. This means that without subsidies farmers are WTP an 18.62% premium for heat-tolerant varieties compared to the average seed price paid for another commercial hybrid. These results match those of a study [44] that found that consumer WTP was 13.8% higher than the average price of non-genetically modified (GM) maize meal. They are also in agreement with a study in Zimbabwe that found drought tolerance to be the most preferred trait among smallholder Zimbabwean farmers compared to other traits such as yield, cob size, and flint texture [50]. A study revealed that Ethiopian farmers have been willing to sacrifice 3.1 quintals/0.25 ha yield to have the drought tolerance trait in a variety [51]. The Nepalese government gives a 50% subsidy on national hybrid maize seeds to promote the adoption of heat-tolerant hybrid seeds among farmers. If farmers receive maize hybrid seed from their co-operatives, distributed through the Prime Minister Agriculture Modernization Project (PMAMP) and the Smart Krishi village project, they receive a 50% subsidy. The subsidized seed price of Rampur Hybrid-10 is NPR 236.52 (USD 2.00)/kg, whereas the price is NPR 405.15 (USD 3.43)/kg for other conventional hybrids that exist in the market. The seed price of Rampur Hybrid-10 is less because it is produced and marketed by Nepalese seed companies and transportation and storage costs are minimized, whereas the high seed price of a conventional hybrid is because it is imported from India and includes transportation, storage, and marketing costs. The price of Indian hybrid maize seed ranges from NPR 270 (USD 2.27) to NPR 800 (USD 6.77)/kg without the subsidy. Without considering the subsidy, farmers are willing to pay NPR 557.57 (USD 4.72)/kg for Rampur Hybrid-10. Farmers receive a good quality heat-tolerant maize hybrid with a reasonable seed price due to the advantage of seed being produced by local seed companies. In order to obtain good quality seed, farmers in Kenya

were willing to pay a 15% premium, on average, for bags purchased directly from the seed company compared to mint condition bags purchased from local retailers [52].

**Table 6.** Relationship between land ownership, hybrid maize adoption, and WTP for heat-tolerant hybrids.

Land Owned (ha)	Number of Households			Mean WTP (NPR/kg)			Mean Difference
	Hybrid Maize Adopters	Non-Adopters/ OPV	Overall	Hybrid Maize Adopters	Non-Adopters/ OPV	Overall	
≤0.50	141	33	174	593.89	418.40	560.61	175.49 ***
0.51–1.00	115	7	122	573.27	446.67	56.600	126.60 ***
1.01–1.50	43	5	48	544.44	457.42	535.37	87.02 **
>1.50	58	2	60	551.95	475.10	549.39	76.85
Overall	357	47	404	574.46	429.18	557.57	145.28 ***

\*\*\* and \*\* = statistically significant at 1% and 5% levels, respectively.

Hybrid maize growers were WTP NPR 574.46/kg for heat-tolerant maize hybrids, whereas OPV farmers' WTP amounted to NPR 429.18/kg; the difference was statistically significant, and hybrid growers were WTP an NPR 144.28/kg premium for a heat-tolerant maize hybrid. A significant difference was observed between the WTP among hybrid maize adopters and non-adopters (those growing OPVs/local varieties). As the land holding sizes of hybrid adopters increased, the WTP for heat-tolerant hybrids slightly decreased, whereas as land holding increased, the WTP of non-hybrid adopters increased (Table 6). Therefore, government extension agencies need to focus on promoting heat-tolerant maize hybrids among OPV maize farmers in order to deliver climate-smart agriculture technologies to them.

#### 4.7. Demand Heterogeneity

The mean WTP for heat-tolerant maize hybrids across the years of cultivation and membership in farmers' networks is presented in Table 7. The result is based on the interval regression model in Table 5 (model 2). The results show that the mean WTP for farmers who did not have any experience in maize hybrid cultivation was NPR 429.17/kg. Farmers with 5 years of experience or less were willing to pay NPR 549.34/kg, which was 28% more than what farmers with no experience were willing to pay. Farmers with more than 5 years of experience were willing to pay NPR 595.55/kg, which was 8.41% more than what farmers with 1 to 5 years of maize hybrid cultivation were willing to pay and 38.77% more than what farmers with no experience were willing to pay. It is clear that there was a positive relationship between the WTP and experience in hybrid maize cultivation.

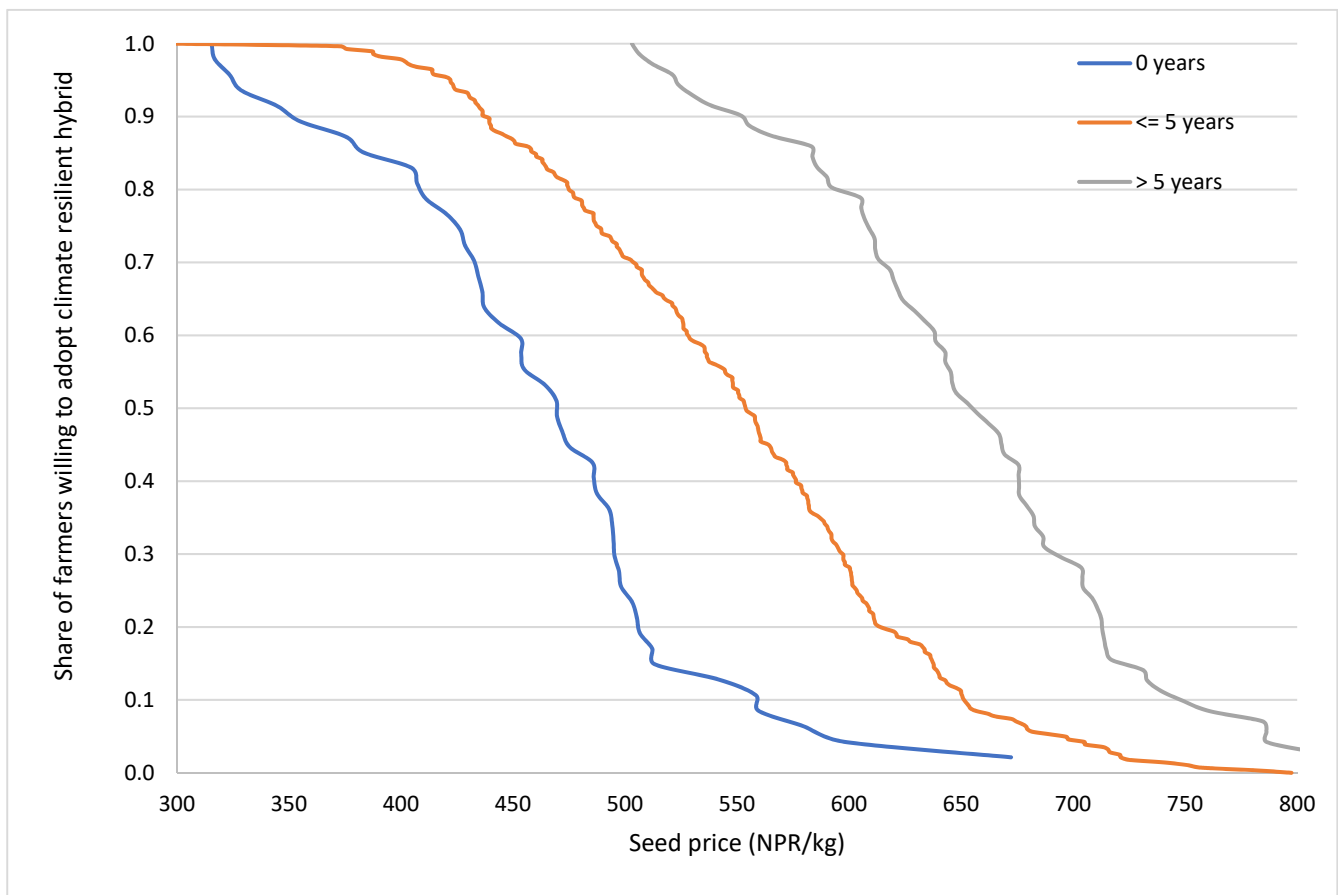
**Table 7.** Estimated WTP for heat-tolerant maize hybrids based on whether farmers were growing hybrid maize, their membership in farmer networks, and the gender of the household head.

	Mean WTP, Predicted (NPR/kg)	SD of WTP	Mean Difference
Years of hybrid maize cultivation			
None	429.17	74.92	-
1–5 years	549.34	88.68	120.17 ***
>5 years	595.55	65.44	166.38 ***
<5 years and >5 years	595.55	88.68	46.21 ***
Member of farmers' network			
Not a member of any group	472.91	94.69	-
Member of any group	571.77	76.84	98.95 ***
Member of co-operative	569.52	77.06	96.61 ***
Member of farmers' club	602.94	71.03	130.03 ***
Member of both co-operative and farmers' club	610.75	69.88	137.84 ***
Gender of household head			
Female	504.21	100.18	-
Male	562.48	83.88	58.27 ***

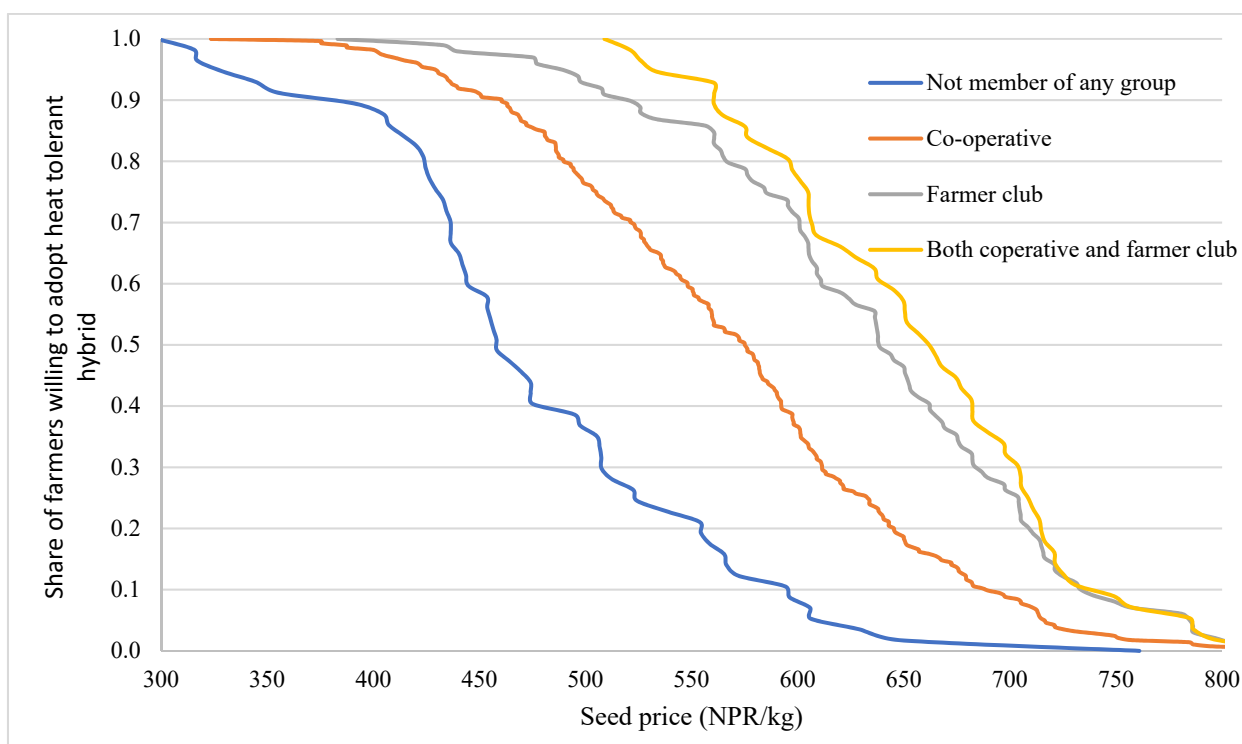
\*\*\* = statistically significant at the 1% level. Exchange rate USD 1 = NPR 118.13 [41].

Farmers affiliated with any network group were willing to pay 20.90% more than those not affiliated with any farmer group [39]. Farmers who were members of a co-operative society, farmers' club, or both were willing to pay 20.42%, 27.50%, and 29.15% more, respectively, than those not associated with any group. Finally, male-headed households were willing to pay 11.55% more than female-headed households.

The demand curves for heat-tolerant maize varieties in relation to years of experience in hybrid maize cultivation is presented in Figure 3, and the demand curves in relation to their membership in farmers' network groups is presented in Figure 4. Overall, all demand curves were elastic. The demand curve with zero years of experience in hybrid maize cultivation and the demand curve of households that were not a member of any group were highly elastic compared to the other groups. Farmers with more years of hybrid maize cultivation had a higher demand for heat-tolerant varieties than those with few years of experience, and as the experience increased, the demand for heat-tolerant varieties increased. Farmers with membership in network groups had a higher demand curve than those who were not members. The Government of Nepal has been promoting activities to increase the adoption of hybrid maize in the Terai region and other regions of Nepal. Liberalizing the hybrid maize seed market in 2011 created an opportunity for regional seed companies to enter the Nepalese market and formally register their hybrids [35]. The results of the differential demand curves could be useful to the private sector in quantifying the potential market for heat-tolerant maize varieties in maize-growing regions.



**Figure 3.** Estimated farmer demand curves for heat-tolerant maize varieties in relation to years of hybrid maize cultivation.



**Figure 4.** Estimated farmer demand curves for heat-tolerant maize varieties in relation to membership in network groups.

## 5. Conclusions

Temperature is a major environmental factor that determines maize's physiological development and yield. Extremely high and low temperatures coincide with critical stages of crop growth, such as the reproductive stage, with adverse effects on crop yield. The development of heat-tolerant maize varieties is needed to enhance the resilience of maize production under heat-stressed conditions. Global research institutions such as the International Maize and Wheat Improvement Center (CIMMYT), in collaboration with national research stations such as the National Maize Research Station (NMRRP, Nepal), developed heat-tolerant hybrids to address heat stress issues. In this context, the current study assessed smallholder farmers' WTP for heat-tolerant maize hybrids in the Terai region of Nepal. Our results show that education, owned land, the interaction of hybrid adopters and own land, the number of goats/sheep owned, and households living in semi-*pucca* homes influenced the WTP for heat-tolerant maize hybrids. Our results demonstrate that farmers' average WTP was 71% higher than the actual price of other conventional maize varieties, including all seed sources.

The findings of this study show a heterogeneous demand for heat-tolerant maize varieties with respect to years of experience in hybrid maize cultivation, membership in networks, and the gender of the household head. We found that among farmers with more than 5 years of experience in hybrid maize cultivation, the WTP was 38% more than among farmers with no experience in hybrid maize cultivation or those who have cultivated OPVs and local varieties. This shows that farmers who adopt hybrid maize obtain a greater yield advantage compared to OPVs, which is the reason why they are willing to pay a premium price for heat-tolerant maize hybrids. In-country seed production of Rampur Hybrid-10 further enhanced the overall maize seed ecosystem in the country.

### *Policy Implications*

1. Since OPVs cannot fulfil the increasing demand for maize, agriculture extension agencies and seed companies should target farmers growing OPV maize in their promotion of heat-tolerant maize hybrids.
2. Imparting training on cultural practices in hybrid maize cultivation at the village level will speed up adoption.
3. Increasing demand for hybrid maize seed among farmers and a shortage in the supply of domestic hybrid seed provide an opportunity for domestic seed companies to produce hybrid seed that not only increases production and productivity but also reduces import costs.
4. The Nepalese government is promoting the adoption of hybrid and heat-tolerant maize through different distribution and promotional schemes. The government could devise a policy wherein hybrid seed is subsidized only if it is produced by domestic seed companies, or it could give more incentives for locally produced hybrid seed instead of importing hybrid seed.
5. Involving 13 private seed companies in heat-tolerant maize hybrid seed production has been one of the biggest outcomes of the HTMA project and a great example of public–private partnership in the research, development, and deployment of new stress-resilient varieties in partner countries. Continuing the project collaboration with the National Maize Research Program (NMRP) under NARC and with private seed companies with the technical support of CIMMYT for the next five years could achieve excellence in breeding techniques and increase seed production per unit area in Nepal.
6. Strengthening backward and forward linkages for the commercialization of domestic maize hybrids through NMRP, in collaboration with PMAMP and other private partners, will enable domestic companies to invest in hybrid maize seed production for the sustainable development of the maize seed ecosystem.
7. Nepal’s good network of co-operative societies can be used as outlets for the distribution of heat-tolerant hybrids directly from seed companies so that they are made available to farmers at a reasonable price.

**Supplementary Materials:** The following supporting information can be downloaded at: <https://www.mdpi.com/article/10.3390/su15043068/s1>, Table S1. Break-up of economics of Maize production in Nepal.

**Author Contributions:** A.P.K.: Methodology, Software, Formal analysis, Investigation, Data Curation, Writing—Original Draft, and Visualization. M.P.T.: Resources and Writing—Review and Editing. D.G.: Methodology, Investigation, and Resources. K.B.K.: Investigation, Resources, Writing—Review and Editing, and Supervision. M.K.: Investigation and Resources. D.R.: Investigation and Resources. S.S.: Resources and Writing—Review and Editing. P.H.Z.: Conceptualization, Validation, Supervision, and Project administration. All authors have read and agreed to the published version of the manuscript.

**Funding:** This research was conducted as a part of “Heat Tolerant Maize for Asia (HTMA)” project, which was funded by the United States Agency for International Development (USAID) and implemented by the researchers at the International Maize and Wheat Improvement Center (CIMMYT), Hyderabad, India. Funding Number MTO No. 069033.

**Institutional Review Board Statement:** For all socioeconomic surveys and data collection from family or community representatives, the Institutional Research Ethics Committee (IREC) of the International Maize and Wheat Improvement Center (CIMMYT) classified this study as having no risk for human subjects and approved the study. Relevant IREC guidelines and regulations were followed.

**Informed Consent Statement:** The front page of each questionnaire carried a section where the person being interviewed indicated her/his informed consent for the interview. Interviewers were trained and required to read the consent statement aloud to each interviewee before the interview could advance. Participants were informed that they were under no obligation to answer any questions and could stop the interview at any time, without giving any reasons, and could ask for any partial data to be removed from the records.

**Data Availability Statement:** Data will be made available on request.

**Acknowledgments:** We gratefully acknowledge Vijesh Krishna for reviewing the manuscript and helping in analysis and Vinayan for sharing the field trial data. We are thankful to PMAMP and the co-operative societies for sharing the adopter farmer list and other necessary information. We gratefully acknowledge the farmers for taking the time to participate in the survey.

**Conflicts of Interest:** The authors declare no conflict of interest.

### Appendix A. Format of Willingness to Pay Questionnaire

Maize breeders are developing varieties that are less affected by heat stress at flowering stage. Other production and consumption characteristics of the varieties (e.g., yields under normal conditions, grain quality, and green fodder mass, etc.) will be the same as those currently available. But this seed will make your yield more stable under heat stress.

1.1	Whether your favorite maize variety is heat tolerant at the flowering state?	Yes = 1 No = 0 No idea = 3
1.2	Would you be willing to pay NPR 500/kg for this improved seed that is more likely adapted to heat stress at flowering stage?	Yes = 1 No = 0
1.3	If yes, would you pay NPR 600/kg	Yes = 1 No = 0
1.4	If no, would you pay NPR 350/kg	Yes = 1 No = 0
1.5	Do not want to buy the variety seed at the given price	1 = Do not want to buy

### References

- World Population Prospects: The 2019 Revision—United Nations Population Division. Available online: <https://www.worldometers.info/world-population/> (accessed on 26 May 2022).
- Bergvinson, D.J. Enhancing maize productivity in drought-prone environments in East and Southeast Asia. In *RETA No. 6208, First Annual Report*; International Maize and Wheat Improvement Center (CIMMYT): Veracruz, Mexico, 2006.
- Nelson, G.C.; Rosegrant, M.W.; Koo, J.; Robertson, R.; Sulser, T.; Zhu, T.; Ringler, C.; Msangi, S.; Palazzo, A.; Batka, M.; et al. *Climate Change Impact on Agriculture and Costs of Adaptation*; International Food Policy Research Institute (IFPRI): Washington, DC, USA, 2009.
- Grant, R.F.; Jackson, B.S.; Kiniry, J.R.; Arkin, G.F. Water deficit timing effects on yield components in maize. *Agron. J.* **1989**, *81*, 61–65. [[CrossRef](#)]
- Dlobell, B.; Burke, M.B. On the use of statistical models to predict crop yield responses to climate change. *Agric. Forest Meteorol.* **2010**, *150*, 1443–1452. [[CrossRef](#)]
- Lal, M. Climate change—Implications for India's water resources. In *Climate Change and Water Resources in South Asia*; Mirza, M.M.Q., Ahmad, Q.K., Eds.; A.A. Balkema Publishers (Taylor & Francis Group): Lieden, The Netherlands, 2005; pp. 155–193.
- Lal, M. Implications of climate change in sustained agricultural productivity in South Asia. *Reg. Environ. Chang.* **2011**, *11*, 79–94. [[CrossRef](#)]
- Hijioka, Y.; Lin, E.; Pereira, J.J. Asia. In *Climate Change 2014 Impacts, Adaptation, and Vulnerability Part A: Global and Sectoral Aspects*; Field, C.B., Barros, V.R., Eds.; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2014; pp. 1327–1370.
- Tesfaye, K.; Zaidi, P.H.; Gbegbelegbe, S.; Boeber, C.; Rahut, D.B.; Getaneh, F.; Seetharam, K.; Stirling, C. Climate change impacts and potential benefits of heat-tolerant maize in South Asia. *Theor. Appl. Climatol.* **2017**, *130*, 959–970. [[CrossRef](#)]
- WFP (World Food Programme). Winter Drought Worsens Food Insecurity in Nepal. 2009. Available online: <https://reliefweb.int/report/nepal/winter-drought-worsens-food-insecurity-nepal> (accessed on 5 May 2022).

11. Solomon, S.; Qin, D.; Manning, M.; Chen, Z.; Marquis, M.; Averyt, K.B.; Tignor, M.; Miller, H.L.; IPCC (Intergovernmental Panel on Climate Change). *Climate Change 2007: The Physical Science Basis; Contribution of Working Group I to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change*; Cambridge University Press: Cambridge, UK; New York, NY, USA, 2007.
12. UNEP (United Nations Environment Programme). *Freshwater under Threat South Asia: Vulnerability Assessment of Freshwater Resources to Environmental Change*. 2008. Available online: [www.roap.unep.org/pub/](http://www.roap.unep.org/pub/) (accessed on 8 November 2022).
13. Bates, B.C.; Kundzewicz, Z.W.; Wu, S.; Palutikof, J.P. *Climate Change and Water. Technical Paper of the Intergovernmental Panel on Climate Change*; IPCC Secretariat: Geneva, Switzerland, 2008; p. 210.
14. NCVST. *Vulnerability Through the Eyes of Vulnerable: Climate Change Induced Uncertainties and Nepal's Development Predicaments*; Institute for Social and Environmental Transition-Nepal (ISET-N): Kathmandu, Nepal; Institute for Social and Environmental Transition (ISET, Boulder, Colorado) for Nepal Climate Vulnerability Study Team (NCVST): Kathmandu, Nepal, 2009.
15. McSweeney, C.; New, M.; Lizcano, G. UNDP Climate Change Country Profiles: Nepal, 2008. Available online: <http://countryprofiles.geog.ox.ac.uk> (accessed on 20 May 2022).
16. CHendrix, S.; Glaser, S.M. Trends and Triggers: Climate Change and Civil Conflict in Sub-Saharan Africa. *Political Geogr.* **2007**, *26*, 695–715. [[CrossRef](#)]
17. Lybbert, T.J.; Bell, A. Stochastic benefit streams, learning, and technology diffusion: Why drought tolerance is not the new bt. *AgBioForum* **2010**, *13*, 13–24.
18. Edmeades, G.O. *Drought Tolerance in Maize: An Emerging Reality*; A Feature In James, Clive, (39, ISAAA Brief); International Service for the Acquisition of Agri-Biotech Applications (ISAAA): Manila, Philippines, 2008.
19. Lobell, D.B.; Burke, M.B.; Tebaldi, C.; Mastrandrea, M.D.; Falcon, W.P.; Naylor, R.L. Prioritizing climate change adaptation needs for food security in 2030. *Science* **2008**, *319*, 607–610. [[CrossRef](#)]
20. World Bank. Agricultural Irrigated Land (% of Total Agricultural Land)—Nepal. 2010. Available online: <https://data.worldbank.org/indicator/AG.LND.IRIG.AG.ZS?locations=NP> (accessed on 8 May 2022).
21. Bahadur, K.C.D.; Gadal, N.; Neupane, S.P.; Puri, R.R.; Khatiwada, B. Maize Seed Marketing Chains and Marketing Efficiency along Supply Chains of the Hills in Nepal. *Int. J. Agric. Mark.* **2015**, *2*, 26–33.
22. MoALD. *Statistical Information on Nepalese Agriculture 2076/77 (2019/20)*, Ministry of Agriculture and Livestock Development, Planning and Development Cooperation Division, Statistics and Analysis Section; Singha Durbar: Kathmandu, Nepal, 2021; p. 1.
23. Ministry of Finance. *Economic Survey 2020-21*; Ministry of Finance: Kathmandu, Nepal, 2020; p. 106.
24. Koirala, K.B. Maize Research for Food, Feed and Nutritional Security in Nepal. In *Proceedings of the 29th Summer Crops Workshop, Kaski, Nepal, 17–18 June 2018*; Bhandari, D., Upreti, H.K., Shrestha, R., Tripathi, J.J., Shrestha, H.K., Mishra, K.K., Joshi, B.K., Ansari, A.R., Tripathi, B.P., Bandy, S., et al., Eds.; Regional Agricultural Research Station: Kaski, Nepal, 2020; pp. 7–19.
25. Ranum, P.; Pena-Rosas, J.P.; Garsia-Casal, M.N. Global maize production, utilization, and consumption. *Ann. N. Y. Acad. Sci.* **2014**, *1312*, 105–112. [[CrossRef](#)]
26. Sapkota, D.; Pokhrel, S. Community based maize seed production in the hills and mountains of Nepal: A review. *Agron. J. Nepal* **2020**, *1*, 107–112. [[CrossRef](#)]
27. MoAD, *Statistical Information on Nepalese Agriculture 2017/18*; Government of Nepal, Ministry of Agricultural Development, Agribusiness Promotion and Statistics Division, Singhadurbar: Kathmandu, Nepal, 2019.
28. MoALD. *Statistical Information on Nepalese Agriculture 2075/76 (2018/19)*; Ministry of Agriculture and Livestock Development, Planning and Development Cooperation Division, Statistics and Analysis Section, Singha Durbar: Kathmandu, Nepal, 2020; p. 435.
29. Sharma, M.; Pudasaini, A. Where is Nepal in the food system transition? *South Asian J. Soc. Stud. Econ. (SAJSSE)* **2020**, *8*, 16–36. [[CrossRef](#)]
30. Koirala, K.B.; Giri, Y.P.; Rijal, T.R.; Zaidi, P.H.; Sadananda, A.R.; Shrestha, J. Evaluation of grain yield of heat stress-resilient maize hybrids in Nepal. *Int. J. Appl. Sci. Biotechnol.* **2017**, *5*, 511–522. [[CrossRef](#)]
31. *Heat and Drought Stress Impacts on Corn*; Agronomic Alert; Monsanto Technology Development and Agronomy: Creve Coeur, MO, USA, 2012; p. 3.
32. Koirala, K.B.; Adhikari, J.B.; Tripathi, M.P. On-farm evaluation of hybrid maize in different ecologies of Nepal. *Azarian J. Agric.* **2020**, *7*, 84–92. [[CrossRef](#)]
33. Govind, K.C.; Karki, T.B.; Shrestha, J.; Achhami, B.B. Status and prospects of maize research in Nepal. *J. Maize Res. Dev.* **2015**, *1*, 1–9.
34. Upadhyay, N.; Timsina, K.P.; Gairhe, S.; Sapkota, S.; Acharya, Y.; Khadka, S. Growth of livestock sector in Nepal: Perspective on agricultural perspective plan. In *Proceeding of the 10th National Workshop on Livestock and Fisheries Research in Nepal, Kathmandu, Nepal, 5–7 March 2017*; pp. 364–372.
35. Paudel, G.P.; Krishna, V.V.; Rahut, D.B.; McDonald, A.J. Sustainable intensification under resource constraints: Estimating the heterogeneous effects of hybrid maize adoption in Nepal. *J. Crop Improv.* **2022**, 1–26. [[CrossRef](#)]
36. *National Population and Housing Census 2011 (National Report)*; Central Bureau of Statistics: Kathmandu, Nepal, 2012; p. 208.
37. Yamane, T. *Statistics: An Introductory Analysis*, 3rd ed.; Harper and Row: New York, NY, USA, 1973.
38. Mitchell, R.C.; Carson, R.T. *Using Surveys to Value Public Goods: The Contingent Valuation Method*; Resources for the Future: Washington, DC, USA, 1989.

39. Batman, I.A.; Carson, R.T.; Day, B.; Hanemann, M.; Hanley, N.; Hett, T.; Jones-Lee, M.; Loomes, G.; Mourato, S.; Özdemiroglu, E.; et al. *Economic Valuation with Stated Preference Techniques: A Manual*; Edward Elgar: Cheltenham, UK, 2002.
40. MHanemann; Loomis, J.; Kanninen, B. Statistical efficiency of double bounded dichotomous choice contingent valuation. *Am. J. Agric. Econ.* **1991**, *73*, 1255–1263. [[CrossRef](#)]
41. World Bank. 2021. Available online: <https://data.worldbank.org/indicator/PA.NUS.FCRF?locations=NP> (accessed on 11 March 2021).
42. Asfaw, S.; Shiferaw, B.; Simtowe, F.; Lipper, L. Impact of modern agricultural technologies on smallholder welfare: Evidence from Tanzania and Ethiopia. *Food Policy* **2012**, *37*, 283–295. [[CrossRef](#)]
43. Kostandini, G.; Abdoulaye, T.; Erenstein, O.; Sonder, K.; Guo, Z.; Setimela, P.; Menkir, A. Potential Impacts of Drought Tolerant Maize: New Evidence from Farm-trials in Eastern and Southern Africa. In Proceedings of the 89th Annual Conference of the Agricultural Economics Society, University of Warwick, Coventry, UK, 13–15 April 2015.
44. Wossen, T.; Abdoulaye, T.; Alene, A.; Haile, M.; Feleke, S.; Olanrewaju, A.; Manyong, V. Impacts of extension access and cooperative membership on technology adoption and household welfare. *J. Rural. Stud.* **2017**, *54*, 223–233. [[CrossRef](#)]
45. Kimenju, S.C.; Groote, H.D. Consumer willingness to pay for genetically modified food in Kenya. *Agric. Econ.* **2008**, *38*, 35–46. [[CrossRef](#)]
46. Krishna, V.V.; Quim, M. Estimating the adoption of Bt eggplant in India: Who Benefits from public-private partnership? *Food Policy* **2007**, *32*, 523–543. [[CrossRef](#)]
47. Ghosh, B.K. Determinants of farm mechanization in modern agriculture: A case study of Burdwan districts of West Bengal. *Int. J. Agric. Res.* **2010**, *5*, 1107–1115. [[CrossRef](#)]
48. Jha, R.; Chitkara, P.; Gupta, S. Productivity, technical and allocative efficiency and farm size in wheat farming in India: A DEA approach. *Appl. Econ. Lett.* **2000**, *7*, 1–5. [[CrossRef](#)]
49. Jha, R.; Rhodess, M.J. Some imperatives of the green revolution: Technical efficiency and ownership of inputs in Indian agriculture. *Agric. Resour. Econ. Rev.* **1999**, *28*, 57–64. [[CrossRef](#)]
50. Kassie, G.T.; Abdulai, A.; MacRobert, J.F.; Abate, T.; Shiferaw, B.; Tarekne, A.; Maleni, D. Willingness to pay for drought tolerance (DT) in maize in communal areas of Zimbabwe. In Proceedings of the 88th Annual Conference of the Agricultural Economics Society, AgroParisTech, Paris, France, 9–11 April 2014.
51. Marenya, P.; Wanyama, R.; Alemu, S.; Westengen, O.; Jaleta, M. Maize variety preferences among smallholder farmers in Ethiopia: Implications for demand-led breeding and seed sector development. *PLoS ONE* **2022**, *17*, e0274262. [[CrossRef](#)] [[PubMed](#)]
52. Gharib, M.H.; Palm-Forster, L.H.; Lybbert, T.J.; Messer, K.D. Fear of fraud and willingness to pay for hybrid maize seed in Kenya. *Food Policy* **2021**, *102*, 102040. [[CrossRef](#)]

**Disclaimer/Publisher’s Note:** The statements, opinions and data contained in all publications are solely those of the individual author(s) and contributor(s) and not of MDPI and/or the editor(s). MDPI and/or the editor(s) disclaim responsibility for any injury to people or property resulting from any ideas, methods, instructions or products referred to in the content.