Improving the livelihoods of dryland farmers through the introduction of potato cropping: a proposal based on detailed SWOT analysis

Rajesh K. Rana[1], Sushma Arya[2], S. Kumar[3], T. Cecilia[4], V. Mares[4], R. Quiroz[4], S. Kumar[5] and M.S. Kadian[2]

[1] *ICAR–National Institute of Agricultural Economics and Policy Research, DPS Marg, Pusa-110 012, New Delhi, India (The survey was conducted at ICAR-Central Potato Research Institute, Shimla-171 001, HP, India)*

[2] *International Potato Centre, SWSA, DPS Marg, NASC Complex, New Delhi-100 012, India*

[3] *ICAR-Central Potato Research Institute, Shimla-171 001, HP, India*

[4] *International Potato Centre, Apartado 1558, Lima 12, Peru*

[5] *International Crop Research Institute for the Semi-Arid Tropics, Patancheru–502 324, Telangana, India*

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Acronyms and abbreviations

APMC:	Agricultural Produce Marketing Committee
CAZRI:	Central Arid Zone Research Institute (Jodhpur, India)
CIP:	International Potato Centre
CPRI:	Central Potato Research Institute
DES:	Directorate of Economics and Statistics (Ministry of Agriculture, Government of India)
FAO:	Food and Agriculture Organization
GRAVIS:	Gramin Vikas Vigyan Samiti (An NGO headquartered at Jodhpur, India)
ICAR:	Indian Council of Agricultural Research (India)
MNREGA:	Mahatma Gandhi National Rural Employment Guarantee Act
NCR:	National Capital Region (India)
NGO:	Non-Government Organisation
NIAP:	National Institute for Agricultural Economics and Policy Research (New Delhi, India)
SWCA:	South West and Central Asia

SWOT: Strength, Weakness, Opportunity and Threat

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Executive summary

FAO has identified potato as a crop for ensuring future food security for the global poor, particularly in the developing countries. Strength of this analysis was demonstrated in India during 2003 and 2013 in terms of tremendous growth in potato production, productivity and area. Further, India aims to produce 125 million t potatoes (45.34 million t during 2013) by the year 2050 for ensuring food security of its natives. However, potato production in India has been regional in nature and farmers in non-traditional areas wish to cultivate potatoes for augmenting their farm incomes in order to meet their fast increasing family expenses. Rajasthan, an arid area dominated state, is not an important producer of potatoes and whatever production of the crop is harvested in the state majority of it (nearly 85%) falls in districts adjoining to major potato producing states. Jodhpur district of the state is not at all known at state level as a potato producing district. However, International Potato Centre (SWCA), New Delhi has identified some potential locations where potato cultivation can be successfully introduced. A survey study was carried out in February 2015 in the selected villages of the state for assessing detailed socio-economic and agro-climatic feasibility of introducing potato crop in the area for socio-economic upliftment of the farmers. For this study 110 respondents were interviewed from four villages out of which two villages were the action villages under Dryland Systems Consortium Research Program (CRP 1.1).

Strengths, weaknesses, opportunities and threats (SWOT) analysis of socio-economic and agro-climatic variables in the study area was carried out for presenting real scenario for informed decision on introduction of potato crop. Suitable temperature, lower relative humidity, higher sunshine hours, suitable soils, favourable average wholesale potato

prices, availability of farm labour, higher estimated potato crop profitability than existing and potential new introductions, nearness to the markets, semi-durability of the produce enabling farmers to choose selling time and possibility of replacement of wheat by potato crop are the strong points suggesting introduction of potato crop in the area. However, meagre precipitation and scarce availability of irrigation water, relatively weak transfer of technology mechanism and poor technical knowhow of the existing farmers even on exiting crops, hassle of procuring quality seed potato particularly by small and marginal farmers, inadequate experience of potato growing in the area and wild life infestation of the area are some important existing weaknesses in the way of introducing potato crop in this area. It was found that adequate use of technology and technical support by the project implementing agency can ensure successful introduction of the potato crop in the study area. Similarly the project implementing agency will have the opportunities of generating some indirect benefits for the betterment of farmers in the study area. Comprehensive strengthening of capacity building and efficient transfer of technology mechanism of farmers, introducing drip irrigation technology in the area, development of local markets for vegetables, local employment generation, poverty elimination and food security assurance, empowerment of poor women through generating adequate local employment for them are some of such opportunities. There are some potential threats of introducing potato crop in the area and they also need to be adequately addressed before taking decision of introducing potato crop in the study area. Alarmingly deep level of ground water in the study area, possibility of soil salinity by sustained use of very deep saline water, competition from other profitable crops, interruption of local farm labour supply due to political support fetching rural development and employment guarantee schemes like MGNREGA, possible non-receptivity of local farmers to imparted technical knowhow as most of them derive partial livelihood from agriculture, and possible under delivery of already inadequate transfer of technology machinery and some of the important threats.

Introduction

Potato is considered a crop of the future for fighting global hunger and poverty (FAO, 2008) and significant growth in potato production and consumption is occurring, especially in the developing countries (FAOSTAT, 2015). India experienced a potato revolution in the recent past as potato production in the country nearly doubled during 2003 and 2013 (Rana, 2015). This surge in potato production backed by equally proportionate domestic consumption demand was much higher than the population growth rate in the country (Rana, 2015). The assumption of the food security role by the potato crop in India was the sole reason for this production uprising (Singh and Rana, 2013). An analysis of fast changing socio-economic factors in the country confirms long term continuation of the current trend in rapid potato production growth in India (Singh *et al.*, 2015). The country plans to produce 125 million tonne potatoes by the year 2050 (Singh *et al.*, 2015). However, potato production in India has a characteristic 'regional' nature, with the result that farmers of very large number of States get deprived of earning higher profits from potato cultivation (Rana, 2015; Rana *et al*., 2015). Increasing the geographical spread of potato crop across non-traditional potato producing areas (Minhas *et al*., 2011) is very important if India has to successfully achieve the potato production target for the year 2050.

Rajasthan is not known as an important potato growing State in India and most production areas are located in border districts adjoining important potato States like UP, Punjab, Haryana and MP (DES, 2015). Bharatpur and Dholpur districts of Rajasthan bordering the largest potato producing State of India (Uttar Pradesh) account for nearly 75% of potato production in the State while near 7% of Rajasthan's potatoes are produced in Ganganagar district, bordering the State of Punjab (**Figure 1**). Conducive agro-climatic conditions and spill over effect of technological knowhow might be the reason for this pattern. However, the dryland zone Jodhpur district has a negligible potato production to the extent that generally it is not reflected in major records related to potato producing districts in Rajasthan or in India (DES, 2015). CIP India has been conducting field trials for some years and suitable agro-climatic conditions for successful potato cultivation in the district have been reported (Sharma *et al*., 2014).

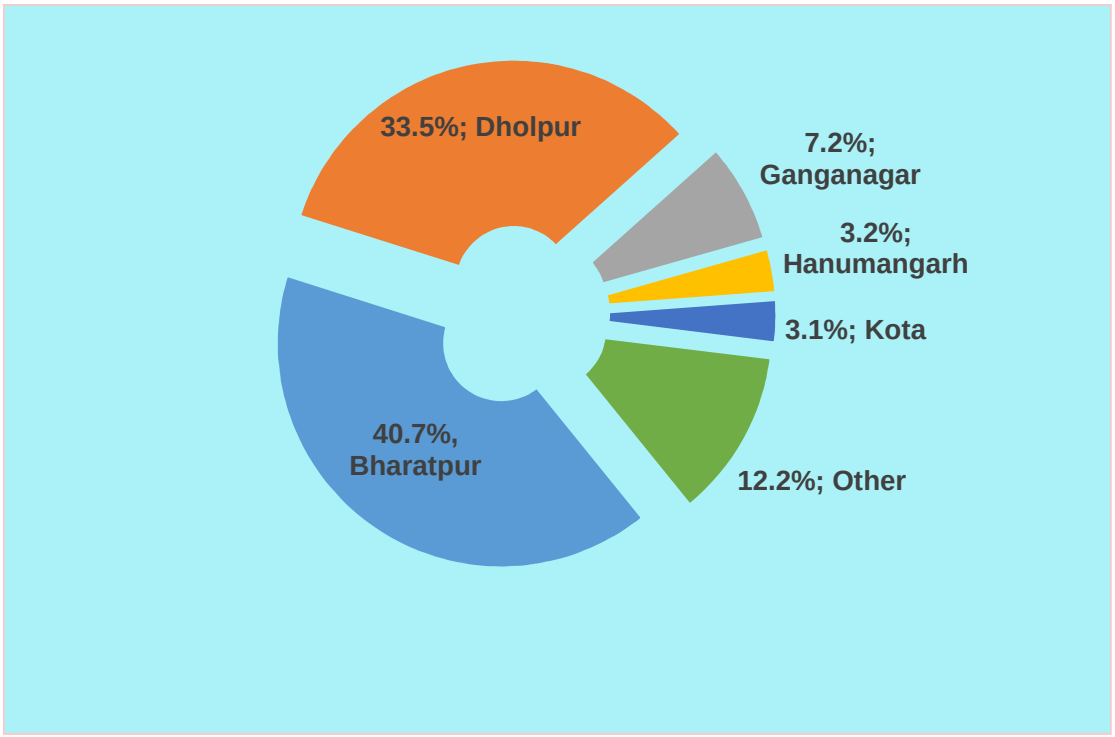

Figure 1: District wise proportional potato production in Rajasthan (TE 2010 and 2011; data source: Directorate of Economics and Statistics, Ministry of Agriculture, Government of India).

Important research efforts have ensured competitive potato cultivation under water stress conditions with drought tolerant and short duration improved potato varieties (Schafleitner *et al*., 2007; Hassanpanah, 2010; Sharma *et al*., 2011; Kadian *et al*., 2012; Monneveux *et al*., 2013; Monneveux *et al*., 2014; Sharma *et al*., 2014). Taking adequate research and development preparedness and agro-climatic suitability of the selected locations in Jodhpur district into consideration, CIP-India and ICAR-Central Potato Research Institute, Shimla planned a joint study to assess the feasibility of introducing potato in this non-conventional area.

Objectives of the study

To assess overall feasibility of potato crop introduction in non-conventional Jodhpur (dryland) district of Rajasthan for socio-economic upliftment of farmers.

Methodology

This study is based on primary as well as secondary sources of data. In order to have socio-economic and agro-climatic information for the introduction of potato into farming systems in Jodhpur, a survey was carried out in February 2015 in Mansagar, Govindpura, Danwara and Bansi villages (Baori block of Jodhpur district), covering 48, 28, 21 and 13 respondents, respectively(**Table 1**). The number of respondents were proportional to the number of farmers in each village. Mansagar and Govindpura are the action villages under the South Asian target region for the Dryland Systems CRP while Danwara and Bansi are the control villages for future impact assessment of the targeted activity.

Table 1: Village-wise sampling details of Jodhpur district of Rajasthan

Village	Nature of village	No. of respondents
Mansagar	Action	48
Govindpura	Action	28
Danwara	Control	21
Bansi	Control	13
Total		110

Results and discussion

This section is based on the analysis of socio-economic and agro-climatic strengths, weaknesses, opportunities and threats (SWOT) as related to the introduction of potato cropping in an un-conventional area.

Strengths

The survey revealed some very strong positive factors for introducing potato in this area with the help of newer technologies like precision farming and drip irrigation system.

Suitable temperature

Potato is highly sensitive to minimum and maximum temperature regimes. Indian potato varieties start failing in tuberization and bulking if the daily minimum temperature remains above 18 to 20^{O}C for a number of days. In addition, if maximum temperature remains above 30 to 32^{O}C then wilting of plants starts. On the other hand, frost severely damages the crop even in isolated incidences. The recommended period of potato cultivation in the study area was the rabi season (October to March; winter season), with an actual crop duration of 90 days or near 13 weeks.

Table 2: Weekly minimum temperature in Jodhpur town during October and March months (^{O}C).

Standard week	Year										
	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
Weekly Data Jan to Mar											
W1	11.7	8.8	11.2	8.8	9.9	9.8	9.1	11.6	12.2	10.7	11.1
W2	10.6	9.2	11.4	11.0	10.3	10.3	10.1	8.0	11.7	12.7	9.5
W3	8.7	11.2	9.3	10.7	12.2	10.9	11.9	10.8	11.4	14.1	10.0
W4	12.4	7.5	8.4	12.9	10.0	9.1	9.9	10.0	9.1	11.8	11.6
W5	9.7	9.6	9.2	12.0	9.8	8.6	14.2	14.5	7.7	11.5	13.6
W6	11.1	11.0	8.6	12.6	8.8	15.8	13.5	15.3	5.3	13.7	13.9
W7	7.9	13.7	11.0	14.0	14.1	13.5	15.6	13.2	9.6	13.8	12.8
W8	13.4	15.5	14.4	14.5	15.4	9.9	16.1	16.9	13.8	16.6	13.9
W9	14.4	15.3	15.2	17.4	15.1	19.0	18.0	15.7	12.8	18.8	17.7
W10	13.1	13.5	17.3	14.0	16.8	17.8	16.9	16.0	18.6	18.7	18.2
W11	16.3	18.1	17.9	17.5	18.0	18.6	18.5	17.1	17.7	18.1	20.1
W12	17.2	20.4	21.0	21.1	20.5	20.4	19.5	19.1	22.4	20.8	21.9
W13	19.8	20.7	20.5	22.2	17.9	21.5	19.0	19.3	22.2	21.7	23.3
W14	21.7	20.5	23.7	22.4	22.5	19.5	23.5	22.9	19.5	21.3	24.4
W15	23.7	22.2	21.7	23.5	25.5	19.2	23.6	22.0	24.5	20.9	26.5
Weekly data Oct to Dec											
W38	24.6	23.7	25.2	25.5	26.0	26.8	25.5	26.8	24.8	25.6	23.1
W39	23.5	21.5	24.6	24.5	26.2	23.5	25.5	24.2	23.7	25.5	20.2

W40	22.1	25.6	22.3	21.3	23.2	21.2	24.1	21.3	25.0	25.9	22.1
W41	22.6	23.1	24.2	19.6	21.5	21.0	20.9	19.0	22.2	23.4	21.3
W42	17.7	18.6	22.1	17.8	19.3	21.2	22.9	15.9	19.3	19.5	23.1
W43	19.0	17.7	18.6	15.3	18.3	16.9	22.3	18.0	17.7	15.3	19.9
W44	16.3	17.7	18.7	17.2	18.4	16.5	19.0	18.4	17.2	18.6	18.5
W45	16.2	17.3	20.3	15.2	16.4	16.8	17.0	17.3	17.0	18.6	19.5
W46	15.9	15.6	15.4	16.0	16.5	14.4	16.3	14.5	16.9	17.7	21.4
W47	12.4	15.4	17.2	15.3	14.4	15.0	16.4	11.8	13.8	12.8	14.9
W48	11.5	11.5	14.8	13.9	14.8	13.3	13.2	13.7	14.3	14.7	12.0
W49	9.8	11.4	14.4	12.8	16.2	11.2	14.6	12.5	18.2	14.4	11.9
W50	12.0	13.1	14.4	12.0	12.3	12.9	11.3	10.8	15.1	16.4	7.0
W51	11.5	12.9	14.1	10.9	11.5	10.3	13.0	11.0	15.6	14.1	8.3
W52	11.9	10.8	11.3	10.4	13.5	9.6	12.4	12.3	9.3	10.7	11.7

Source: ICAR-Central Arid Zone Research Institute, Jodhpur

Long term temperature data of the selected villages was not available due to the absence of any weather station in the localities. To have an approximation to temperature variation trends in the district, long term weekly average minimum and maximum temperature data were obtained from ICAR-CAZRI, Jodhpur (town) situated 65 km from the action villages (Tables 2 and 3). Experts at ICAR-CAZRI, ICRISAT and GRAVIS (local NGO) suggested that temperature variation trends in the target villages and in the town of Jodhpur are similar. However, the day and night temperatures in the villages is 4 to 5^{O}C lower than town of Jodhpur. This advantage of a lower temperature in the study area provides a huge window of opportunity for successfully growing potato in the area, provided all other factors are congenial.

Table 3: Weekly average maximum temperature in Jodhpur town during October and March months (^{O}C).

Standard week	**Year**										
	2000	**2001**	**2002**	**2003**	**2004**	**2005**	**2006**	**2007**	**2008**	**2009**	**2010**
Weekly Data Jan to Mar											
W1	28.3	22.7	26.6	21.4	24.5	23.1	23.1	24.4	24.2	25.3	24.8
W2	26.9	24.2	27.2	24.0	27.5	25.8	25.6	23.2	25.0	23.3	23.4
W3	23.6	27.1	23.1	26.7	27.6	24.2	28.9	26.4	24.9	26.2	26.7
W4	27.1	26.0	23.9	29.0	23.7	21.8	25.4	27.2	20.1	27.1	29.2
W5	26.6	26.5	24.8	23.8	24.1	22.8	31.5	30.0	22.3	28.2	28.9
W6	24.9	29.1	24.0	26.6	27.4	28.3	32.3	29.1	19.6	27.9	29.0
W7	24.4	29.7	27.2	28.6	30.2	28.6	33.5	25.7	27.6	27.3	26.6
W8	28.0	31.7	31.5	26.7	32.2	23.4	36.1	29.8	31.3	32.6	31.1
W9	33.1	30.4	31.6	32.2	34.1	33.4	33.8	28.0	33.3	35.8	35.0
W10	30.1	33.5	32.7	30.2	36.9	32.0	31.6	30.7	34.8	33.8	32.4
W11	32.7	35.9	34.5	32.7	39.9	35.3	31.7	32.9	33.9	36.1	38.2
W12	32.8	35.6	38.4	36.7	40.3	35.2	35.3	33.4	37.9	35.9	40.0
W13	38.3	34.7	37.4	37.3	37.1	35.6	34.6	38.1	38.2	35.0	38.9

W14	39.1	37.9	39.8	39.1	39.6	38.9	39.6	38.7	32.7	37.5	39.7
W15	41.8	37.8	38.7	39.5	40.6	35.1	38.7	39.7	38.9	36.5	41.8
Weekly data Oct to Dec											
W38	37.2	38.0	37.5	36.9	38.4	35.5	38.5	38.5	34.8	39.1	34.1
W39	39.8	41.1	38.8	37.0	38.5	35.0	35.7	36.7	34.5	38.8	35.4
W40	40.5	39.2	40.6	37.9	35.5	37.0	38.5	37.8	38.3	38.5	37.7
W41	38.9	37.9	40.8	37.2	34.8	37.4	35.2	36.0	38.2	36.8	36.4
W42	39.0	37.1	38.4	37.0	35.6	37.6	36.9	36.4	37.0	36.4	36.9
W43	37.8	37.8	36.1	36.6	35.0	35.2	35.0	36.0	37.4	35.6	36.3
W44	35.9	37.7	36.5	35.0	32.7	34.9	34.9	34.8	35.2	36.6	32.4
W45	34.4	32.4	33.8	34.8	32.1	33.2	33.9	35.7	35.2	33.6	32.3
W46	33.5	32.4	29.7	32.5	34.0	33.3	33.2	33.8	31.6	27.4	29.1
W47	30.6	33.5	32.2	27.5	34.4	33.6	30.4	32.7	29.4	29.4	26.0
W48	27.3	30.4	30.7	29.1	30.8	28.5	27.8	30.7	30.5	29.7	26.7
W49	30.1	31.9	28.9	31.7	29.0	27.7	26.3	26.4	32.3	28.6	25.2
W50	30.0	29.8	29.9	27.4	29.4	27.6	24.7	23.4	27.2	27.6	24.6
W51	27.1	26.9	31.2	23.5	28.1	24.8	28.3	26.4	25.0	26.0	26.9
W52	28.5	26.5	25.0	23.4	25.9	26.1	26.0	25.4	27.7	26.0	23.5

Source: ICAR-Central Arid Zone Research Institute, Jodhpur

Low relative humidity

Late blight is one of the biggest production risks in potato cultivation and low relative humidity reduces the probability of disease incidence. Due to low annual precipitation in Jodhpur the relative humidity is lower than in most of the other rabi potato growing areas in the country. Table 4 shows eleven year's relative humidity record of Jodhpur district during rabi season and invariably the maximum humidity have been in the range where chances of major late blight outbreak area negligible. Hence, low relative humidity is another opportunity for farmers of this area to go for successful potato cultivation with lower cost of production.

Table 4: Relative humidity (%) in Jodhpur during selected months.

Year	Jan		Feb		Mar		Oct		Nov		Dec	
	Min	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**	**Min**	**Max**
2000	24.8	67.8	20.1	56.7	16.2	40.2	13.6	46.8	17.7	53.8	23.4	52.7
2001	23.8	60.4	14.6	44.8	12.1	37.6	19.0	56.8	15.2	44.8	17.3	58.5
2002	22.5	58.8	14.1	51.7	12.4	39.5	13.3	40.1	18.1	44.6	22.7	55.6
2003	25.6	60.1	22.4	57.2	12.2	37.9	14.4	43.5	18.1	43.7	23.5	63.3
2004	26.5	69.5	16.8	57.0	7.5	34.4	27.2	58.1	17.1	49.8	23.1	54.5
2005	26.0	62.9	25.8	61.9	18.6	51.5	15.5	49.8	15.7	47.4	17.5	45.0
2006	19.6	54.2	15.7	56.0	16.1	44.1	25.5	58.6	21.5	53.0	28.3	59.4
2007	20.5	52.5	30.7	68.4	19.9	57.0	14.5	45.4	16.5	52.5	25.5	56.2
2008	19.4	43.7	16.7	49.9	13.2	40.7	19.4	55.7	18.0	51.3	29.7	61.2

2009	28.9	61.4	18.8	53.9	16.0	43.6	17.6	50.3	21.5	49.6	26.6	54.1
2010	24.3	68.4	17.1	49.3	13.3	41.3	25.1	60.7	41.4	73.3	28.7	72.5

Source: ICAR-Central Arid Zone Research Institute, Jodhpur

Sunshine hours

Sunshine is very important for plant photosynthesis. However, during rabi season (winter in northern hemisphere) sun irradiance if low. Very large potato growing areas in north-western India experience prolonged foggy conditions during December and January and the crop undergoes considerable productivity and quality loss due to such foggy conditions. However, sunshine conditions are much better in Jodhpur district in general and the action villages in particular.

Suitable soil types

Most of western Rajasthan including Jodhpur possesses deep sandy soils and potato performs extremely well on such soils. Potato tubers from such soils are attractive in colour and tuber bulking is uniform and very smooth. Potato crop in this type of soils gives better yield if nutrient and water management is handled scientifically, compared to most of other soil types. Hence, the type of soil available in the study area is not a limiting factor for potato introduction, rather it is an added benefit.

Favourable potato prices

Azadpur, New Delhi APMC is the leader market for most of fruits and vegetables and potato prices in this market are relatively higher compared to other markets in the major producer areas. The long term (2005 to 2014) potato prices in Jodhpur market have generally remained lower to that of Azadpur market (**Figure 2**), however, lower cost of potato production and marketing in the study area is likely to make up on profitability. In addition, potato growers or traders in the area can seize on the opportunity of selling potatoes in Azadpur APMC in case of a considerable gap in potato prices between these two markets. Hence, favourable potato prices in the area is another positive for introducing this profitable crop in the study area.

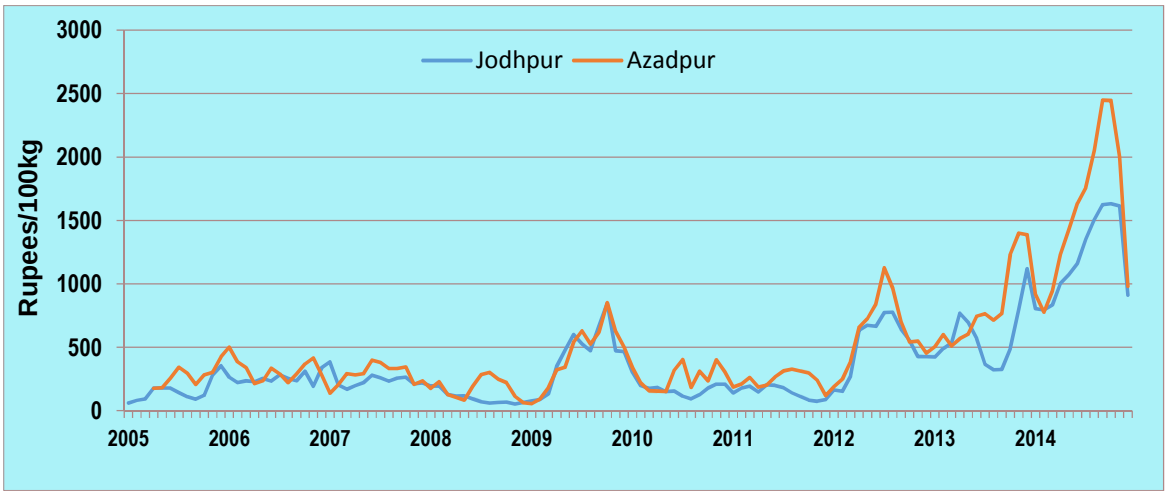

Figure 2: Multi-year inflation adjusted potato prices in Jodhpur and Azadpur markets (agmarknet).

Availability of farm labour

Potato cultivation is labour intensive and can be successfully grown if sufficient farm labour is available in the locality. The selected villages fall in an area where economic activity is not enough to absorb available manpower. This is clearly indicated by the high proportion of respondents' non-working family members and lower proportion of family members working in non-agricultural sectors (Table 5). Hence, the easy and adequate availability of farm labour (**Annexure 1**) is a great positive for possible introduction of potato crop in this area.

Table 5. Village-wise demographic profile of farmers of Jodhpur district in Rajasthan

Characteristic		Village				Overall
		Mansagar	Govindpura	Danwara	Bansi	
Family Size	Total	6.95	5.97	6.33	7.62	6.74
	Male	3.60	3.11	3.33	3.62	3.43
	Female	3.35	2.86	3.00	4.00	3.31
Member engaged in agriculture	Total	3.81	3.47	3.23	3.00	3.38
	Male	1.92	1.79	1.71	1.69	1.78
	Female	1.89	1.68	1.52	1.31	1.60
Members in non-agriculture sector	Total	0.02	0.00	0.05	0.08	0.04
	Male	0.02	0.00	0.05	0.08	0.04
	Female	0.00	0.00	0.00	0.00	0.00
Non-working members@	Total	3.12	2.50	3.10	4.54	3.32
	Male	1.66	1.32	1.62	1.85	1.61
	Female	1.46	1.18	1.48	2.69	1.71

@: Non-working members include unemployed persons, school going children and old persons staying at home.

Higher estimated profitability of potato

Cumin, mustard, castor, psyllium (isbgol), wheat, onion and other miscellaneous crops are grown by the responding farmers. An account of existing crops in the study area has been presented in table 6. Onion is the highest profitable crop among the existing ones in the area. Castor being an annual crop compared poorly with other existing crops while all other crops generated net returns less than Rs. 50000/ha and they can't be considered as high value cash crops. The recent experiences of onion farmers had been less than exciting as they had to struggle at the marketing front due to a slump in prices at the time of harvest.

On farm trials carried out by CIP in the area, potato yields of more than 30 t/ha at 90 days after planting were achieved by three of their clones/ varieties (Sharma *et al*., 2014). Since farmers will try to maximize yields irrespective of harvesting dates, yield levels under best management and input conditions are likely to be still higher. However, to be on safer side the survey team assumed an average target yield of 25 t/ha in the study area. Taking into consideration the spurt in prices of fruits and vegetables in India during recent years farmers will be able to sell their produce at a minimum price of Rs. 8000/t at farm gate. Due to low rental value of land in the study area (average Rs. 18000/ha/year), nearness to potato seed producing area (Punjab State) and relatively high availability of labour (Table 5) the cost of potato cultivation in the area was estimated at Rs. 105000/ha. The conservative estimate for potato crop profitability in the area came out at Rs. 95000/ha. However, if farmers adopt drip irrigation for potato cultivation then their profitability is likely to further improve by 30%. Potato farmers can further improve their profitability by cold storing their produce and selling at a time when potato prices are high. Although carrot cultivation may generate comparable profits, higher marketing risk associated with this crop is a positive for potato crop in the area.

Table 6: Area under different crops in Rabi season and cropping intensity of sampled households (ha)

Particulars	Village(s)				Overall
	Mansagar	Govindpura	Danwara	Bansi	
Castor	0.81	0.67	0.81	0.85	0.79
Cumin	1.10	0.85	1.40	1.13	1.12

Wheat	0.62	0.27	0.62	0.54	0.51
Mustard	0.91	0.73	1.16	0.42	0.81
Isbgol (Psyllium)	0.42	0.46	1.04	0.18	0.53
Onion	0.22	0.44	0.39	0.31	0.34
Others	0.29	0.22	0.18	0.12	0.20
Total *rabi* cultivated	4.37	3.64	5.60	3.55	4.29
Cropped area	10.07	8.33	11.85	7.25	9.38
Cultivable area	5.70	4.68	6.25	3.70	5.08
Cropping intensity (%)	176.67	178.00	189.60	195.94	184.65
Note: Based on the positive responses the average profitability of onion crop was the highest at Rs. 72750/ ha followed by castor (Rs. 66667/ ha), psyllium (Rs. 47036/ ha) and cumin (Rs. 46125/ ha) while all other prevalent crops could attain average profitability less than Rs. 40000/ ha. Although carrot was not grown by many farmers in the study area yet, they were expecting average net returns to the tune of Rs. 95000/ ha at their farms.					

Nearness to the markets

The action villages are situated just about 65 to 70 km away from the Jodhpur city centre. Road transport is quite fast in this part of India due to lower population density which will result in lower marketing cost for the potential potato producers. Hence, nearness to market both in terms of distance as well as time is a big positive for introduction of profitable potato cultivation in this new area.

Semi durable output

Respondents were eager to adopt high value crops at their farms as the existing low value crops were unable to generate sufficient cash flows for satisfying the growing needs of their families. Potato was the number one alternative on the minds of the respondents followed by carrot (Table 7). All other options were supported by very few farmers. Carrot being much more perishable than potato, needs very intense marketing management and simultaneously it is more vulnerable to sudden price slumps in the market. However, potato being semi durable and having the ability of getting stored at household level is a better option for resource poor farmers in the area.

Table 7: Possibilities of growing other crops (index 0-1) for higher average profitability

Crop	Village				Overall
	Mansagar	Govindpura	Danwara	Bansi	
Potato	0.96	1.00	1.00	1.00	0.99
Carrot	0.90	0.75	1.00	1.00	0.91
Groundnut	0.02	0.00	0.00	0.00	0.01

Fenugreek	0.04	0.00	0.00	0.00	0.01
Onion	0.00	0.07	0.00	0.00	0.02
Cotton	0.02	0.00	0.00	0.00	0.01
[#]: Index;0-1 denotes (1.00=100% and 0.10=10% similarly 0.00=0%)					

Possibility of replacement of wheat cropping area with potato

Wheat is an important crop in the area covering nearly 12% of the cultivated land during the *rabi* season (Table 6). However, lower profitability of this crop (average Rs. 32292/ha) and rising profit expectations of farm families made them consider replacement of wheat with some high value crop and potato is one of the most important alternatives on their minds. Hence, farmers' existing favourable opinion about potato cultivation provides a very strong incentive for successful introduction of this crop in the study area. Irrigation water, the crucial input for both wheat and potato, needs to be taken into consideration before suggesting/ recommending such crucial change. Based on their own farm experiments farmers have found no difference in the total water needs of potato and wheat in the area. With the recent strong focus on the development of drought tolerant potato varieties ears (Schafleitner *et al*., 2007; Hassanpanah, 2010; Sharma *et al*., 2011; Monneveux *et al*., 2013; 2014; Sharma *et al*., 2014) the potato crop is expected to consume significantly lower water compared to wheat.

Weaknesses

A comprehensive analysis of various socio-economic, climatic and geographical factors indicates some important weaknesses for introducing potato crop in the study area. However, these weaknesses, elaborated in the following text, can be mitigated or eradicated by the concerted efforts of the project implementation agency.

Limited precipitation and scarce availability of irrigation water

Potato is a water demanding crop that needs regular irrigation for good productivity. But low precipitation (Table 8) and alarmingly deep groundwater level (Table 12) makes water availability a limiting factor for the introduction of potato to farming systems in the area. However, detailed discussion with the respondents revealed that the water needs of the existing wheat crops are higher than the demands of drought tolerant potato

varieties/clones due to the longer growing period of the former crop. It is worth repeating here that farmers are interested in the inclusion of potato to their farming systems due to the potentially higher profitability of the new crop and the influence of the drought tolerant potato varieties developed by CIP and Indian NARS(Schafleitner *et al*., 2007; Rana *et al*., 2011; Sharma *et al*., 2011; Kadian *et al*., 2012; Rana *et al*., 2013; Sharma *et al*., 2013; Monneveux *et al*., 2013; 2014) The possibility of large scale adoption of drip irrigation system (Table 9) in the area is a further incentive for the adoption of potato.

Table 8: Monthly rainfall in Jodhpur District

Month	2000	2001	2002	2003	2004	2005	2006	2007	2008	2009	2010
January	0.0	0.0	0.0	0.7	0.0	0.0	0.0	0.0	0.0	0.0	1.5
February	0.5	0.0	0.7	23.1	0.0	4.0	0.0	22.0	0.0	0.0	0.5
March	0.0	0.0	0.0	2.7	0.0	0.3	0.8	29.1	1.6	2.8	0.0
April	2.5	7.3	4.7	0.0	0.2	5.3	6.0	14.8	24.6	0.4	0.2
May	5.0	33.9	0.6	0.4	0.0	23.3	0.0	1.0	91.4	21.6	0.0
June	19.3	53.5	7.7	64.6	31.5	14.1	21.0	22.3	97.5	21.4	45.4
July	214.1	203.6	0.0	260.3	35.1	132.9	27.7	73.4	66.2	115.2	133.9
August	46.4	113.7	13.8	65.3	139.5	77.2	185.5	77.2	138.8	44.1	120.7
September	3.0	10.6	11.0	1.6	11.1	25.9	29.2	83.7	13.8	6.5	202.9
October	1.5	14.6	0.0	0.0	2.2	0.0	0.0	0.0	0.0	0.0	0.0
November	0.5	0.0	0.6	0.0	0.0	0.0	0.0	0.0	0.0	0.0	39.8
December	0.0	0.0	11.5	0.0	0.2	0.0	0.2	0.2	3.9	0.0	17.3

Source: ICAR-Central Arid Zone Research Institute, Jodhpur

Table 9. Source of irrigation water and methods of irrigation (% responses).

Irrigation source/ method	Village				Overall
	Mansagar	Govindpura	Danwara	Bansi	
Source					
Tube-well	100	100	100	100	100
Method					
Furrow	39	0	24	65	32
Sprinkler	61	100	76	35	68
Drip	0	0	0	0	0
Other	0	0	0	0	0

Lack of technical knowhow and weak transfer of technology

Growers in the study area were asked to elicit reasons for not growing potatoes on their farms. The strongest reason for non-potato cultivation in the area was the lack of technical know-how

about this crop (Table 10) which is a strong weakness in the process of introducing potato cultivation in this area. However, project implementation agencies will have to ensure the transfer of technologies and basic technical know-how to the adopter farmers for at least 3 years. During this period, the project will also have to promote strong linkages between farmers and agricultural extension agencies and the exposure of interested farmers to potato cultivation technologies in other parts of country (e.g. Deesa area in Gujarat). Capacity building in market skills and the development of potato value chains will be important. The heightened focus of the central government of India on augmentation as well as further strengthening of agricultural extension mechanism in the entire country is likely to strengthen the weak transfer of technology mechanism in the study area.

Table 10. Reason for not growing potatoes (% of multiple respondents)

Reason	Village(s)				Overall
	Mansagar	Govindpura	Danwara	Bansi	
Non-traditional crop	19	32	00	00	13
Seed problems	06	03	00	08	04
Lack of technical know how	91	93	100	100	96
Other	13	29	00	00	11

Other responses include lack of marketing facilities, limited agricultural land, wild animals infested area and scarcity of water.

Non availability of quality seed

Seed is one of the most important determinants of crop health and productivity (Chand, 2008). Availability of quality seed is one of the most important factors for successful cultivation of the potato crop (Rana *et al*., 2012; 2013; Sharma *et al*., 2013). Establishing a robust potato seed supply chain in the area by the project implementation agency is very crucial in order to mitigate this weakness. The best local seed potato multiplication mechanism should be identified for ensuring profitability and sustainability of potato cultivation in this area.

Limited number of potato growers

Very few respondents had ever tried to cultivate potato on their farms and none had done it on a regular basis. The scenario in itself doesn't provide an incentive for farmers to readily accept this new crop. In the absence of a convincing demonstration effect, farmers will be more inclined to focus on risks rather than rewards. Although CIP has already cultivated potatoes in the study area with adequate success (Sharma *et al*.,

2014), more and more demonstration experiments needs to be laid down in targeted villages by the project implementation agency.

Wild life infested area

The area is affected by wildlife, particularly the highly harmful wild boar (*Sus scrofa*) and Nilgai (*Boselaphus tragocamelus*). Both these species are known to destroy very large tracts of crops even in a single incidence. The impact and possible solutions were explored in focus group meetings with the affected farmers in the action villages. Due to the elevated level of animal rights activism and strict enforcement of wild life protection act in India it was not possible to suggest/ adopt any control measure involving even the mildest of harm to the animals. However, villagers had adopted a combination of strong metallic fences on high stone pillars and active watch and ward in order to protect crops. These measures were suggested to be fit to protect potato from the wild life effects.

Opportunities

The introduction of potato cropping into farming systems in in a planned and well executed manner is likely to bring some other important opportunities for the land and growers in the area.

Capacity building of farmers

A comprehensive capacity building of the farmers in the target area is an important pre-requisite for successful potato cultivation. The project implementation team shall have to address this important issue during the initial few years. Such capacity building and exposure of farmers to the scientific package and practices of potato cultivation will induce farmers to improve the profitability from other crops also.

Efficient transfer of technology

Inefficient transfer of technology came out as a conspicuous constraint for the development of agriculture in the study area. It was found that the majority of local farmers were not able to derive a satisfactory livelihood from agriculture and they were not following the latest recommended agricultural practices. The overall agricultural technology transfer in the area was inefficient and far behind the ideal and desirable levels. Part of the blame was on the farmers themselves as the majority of them was not

responsive to the advice or recommendations of the agricultural extension functionaries. Repeated interactions with agricultural extension officers and visits to agriculture development offices will enhance the level of confidence and ability to extract/ retain technical knowledge of the farmers. Such positive transformation is likely to benefit farmers in other areas of agriculture and crops.

Use of drip irrigation techniques

Drip irrigation has become a new successful technology in Indian potato cultivation. A survey study based on farmers' personal experiences showed that 33% higher potato yield was reported in Gujarat State (similar agro-climatic conditions than our target area) under drip irrigation (BC Ratio=1.67) compared to furrow irrigation having a BC ratio equal to 1.37 (CPRI, 2012). In a field trial with a row to row distance of 60 cm, plant to plant distance of 10 cm and height of the ridge at 20 cm (tuber at 10 cm depth), Singh *et al*. (2014) reported a potato yield under drip irrigation (with fertigation) equal to 43.1 t/ha compared to furrow irrigation system (30.9 t/ ha). This yield advantage of 39.5% under the drip irrigation system was supported by 2.48 BC ratio against 1.98 for the furrow system. In addition, water savings up to 50%, higher dry matter contents of potato tubers (resulting in higher quality), 10-15% higher number of tubers (making the system further better for seed multiplication), 20-25% higher processing grade tubers (creates an opportunity of getting still better prices for selling raw material to processing industry), 25% fertilizer economy (saving farmers' money and beneficial to the environment) and 30-35% labour economy were also reported by Singh *et al*. (2014).

Development of markets

Potato cropping has a very large proportion of the farm produce as marketable surplus. In addition, development of potato cultivation in the country has been strongly associated with the development of cold storage industry. Hence, introduction of potato crop in the study area is likely to develop physical markets as well as associated businesses particularly the cold storage industry.

Employment generation opportunities

Potato cultivation, particularly in areas where landholdings are small and fragmented, is a labour intensive enterprise. Since the proportion on non-working members of the

respondent families was quite high (Table 5) introduction of potato cultivation is likely to create opportunities for the local labour surplus (**Annexure 1**) in the area.

Poverty reduction and food security

The survey revealed a lack of basic facilities in a large proportion of households (Table 11). The role of potato in poverty reduction and in ensuring food security has been documented (FAO, 2008; Thiele *et al*., 2010; Singh and Rana, 2013). Introduction of potato in this area will contribute to poverty reduction and food and nutritional security.

Table 11. Availability of basic facilities at village level

Particular	Mansagar	Govindpura	Danwara	Bansi	Overall
Individual water connection at home	16.67	14.28	19.05	0.00	12.50
House electrification availability	50.00	46.43	52.38	46.15	48.74
Availability of Sanitation facilities					
Flush toilet	31.25	21.43	47.62	23.08	30.84
Temporary toilet	6.25	0.00	47.62	7.69	15.39
Open field	62.50	78.57	4.76	69.23	53.76
Availability of radio/ transistor	36.17	39.29	52.38	46.15	43.50
Availability of television facility	43.75	10.71	52.38	46.15	38.25
Availability of DTH connection	37.50	7.14	47.62	46.15	34.60

Employment for poor women

Women in the area generally lack ownership of land and decision making opportunities as heads of the family (**Table 12**). Potato cultivation, in addition to being a labour intensive enterprise, is also female labour intensive as many of the operations such as placing seed tuber in the field while planting, weeding, picking of harvested tubers, grading and packing of the harvest are mainly performed by the females in India. Hence, introduction of potato crop in the study area is likely to provide local employment for poor and less or non-literate women in the area finally resulting into women empowerment and balanced social growth.

Table 12. Village-wise demographic profile of farmers of Jodhpur district in Rajasthan

Characteristic	Village	Overall

		Mansagar	Govindpura	Danwara	Bansi	
Family Head (%)	Male	100.00	100.00	100.00	100.00	100.00
	Female	0.00	0.00	0.00	0.00	0.00
Age (Years)		50.31	43.43	50.29	52.23	49.07
Education (No. of schooling years)		5.89	3.89	6.95	5.54	5.57
Participation in groups for augmentation of technical knowhow (%)		0.08	0.04	0.05	0.00	0.04

Threats

Alarmingly deep ground water level

Ground water level in the study area varied between 800 to 1200 feet which is alarmingly adverse. This problem is a concern of most of the respondents (**Table 13**), however, the ambitious proposal of the government of India to adopt inter-linking of rivers in a network mode is likely hope for ground water improvement in the area. In the meantime, potato is a good farming option than wheat, considering its lower water requirements per unit dry matter production.

Table 13. Problem associated with irrigation water

Particulars	Village				Over all
	Mansagar	Govindpura	Danwara	Bansi	
Deep ground water	69.05	50.00	80.95	92.31	73.08
Saline water	11.90	0.00	0.00	0.00	2.98
No issue with water	19.05	50.00	19.05	7.69	23.94

Possibility of soil salinity

Extraction of ground water from a depth ranging from 800 to 1200 feet along with higher salt concentration than the recommended levels in irrigation water may create the problem of soil salinity in the study area. Such development will be quite detrimental for the sustainability of potato cultivation in the area unless salt tolerant potato varieties are further improved and provided to farmers.

Introduction of other profitable crops

Respondents of this survey were eager to adopt cultivation of cash crops in order to meet their growing financial needs. There were other profitable cash crops like carrot which may find favour of local farmers more than potato and this is a potential threat for introducing potato in this area (Table 7).

Rural development schemes of employment

Rural development and employment guarantee schemes like MGNREGA has been very popular with unemployed masses as they get adequate and local employment without undergoing hard-labour in rather meagre alternative employment opportunities. However, negative impact of such schemes on supply of agricultural labour has been experienced in the study area. If such trend is maintained in the long run, then potato cultivation being labour intensive may be highly constrained and farmers may go for large scale mechanization which is still a challenge particularly for small and marginal farmers in India.

Non receptivity of farmers to imparted technical know how

Most of the western Rajasthan state in general and the study area in particular is part of arid agro-climate. Historical agricultural development in the region has long been constrained by production risk due to low and erratic average rainfall. People in this region used diversification as insurance against failure of a particular crop. They had been generally reluctant to adopt capital intensive technologies in order to minimize losses in case of cropfailure. Although the supply of irrigation water in most parts of the region (not in the study area) has moved farmers to adopt improved farming practices it is still difficult for farmers to accept technical recommendations.

Possible under performance of technology transfer

Agricultural extension services in the country are inadequate vis-à-vis the huge diversity of agro-climatic regions and very large number of small and marginal farmers. The extension services tend to serve more responsive and know how demanding farmers rather than smallholders with limited livelihoods from agriculture. Under delivery of extension services could severely limit the adoption of potato cropping in the area.

Conclusions and recommendations

Ever increasing population and shifting consumption patterns in a fast developing country like India necessitates adequate preparedness for affecting pertinent change in the crop diversification at local as well as national level. This initiative of CIP and partners to promote potato cultivation in non-traditional areas is based on a comprehensive SWOT analysis of socio-economic and agro-climatic factors. The analysis suggests some very strong factors supportive of the feasibility of introducing potato cultivation in the study area. However, for addressing scarce availability of irrigation water, drip irrigation technology needs to be introduced in order to slow the progress of ground water depletion in the area unless ambitious proposal of interlinking of Indian rivers materialises. Most of other weaknesses and threats need to be addressed by the project implementing agency for three to five years empowering local farmers to manage critical decisions and activities at their own level for sustained potato cultivation. Project implementing agencies should explain the importance of some crucial policy decisions on overall agricultural development and farmers' profitability in the area and support the right implementation. Some indirect benefits of introducing potato in the study area create other opportunities for the betterment of farmers' livelihood. The detailed analysis of all strengths, weakness, opportunities and threats of this proposal shows the potential benefits of introducing potato cropping into wheat based farming systems in the target area.

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Annexures

Annexure 1: Category-wise workers in the state of Rajasthan and Jodhpur district

Category	Rajasthan	% age of workers	Jodhpur	% age of workers
Cultivators	13618870	19.87	592370	16.07
Agriculture labour	4939664	7.21	242017	6.56
Main workers	21057968	30.72	1056479	28.65
Marginal workers	8828287	12.88	433262	11.75
Total workers	29886255	43.60	1489741	40.40
Total Population	68548437	100.00	3687165	100.00

Source: Directorate of Economics and Statistics (2011), Government of Rajasthan