International Journal of Sustainable Development and Planning
Vol. 15, No. 7, November, 2020, pp. 1081-1087
Journal homepage: http://iieta.org/journals/ijsdp

Priority Analysis on the Production Layout of Potato in China

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https://doi.org/10.18280/ijsdp.150712

Received: 6 May 2020
Accepted: 19 August 2020

Keywords:
production layout of potato, priority, production concentration index (PCI), production advantage, layout planning

ABSTRACT

Based on the panel data 2009-2018 on 23 potato producing areas in China, this paper firstly analyzes the priority of each area in potato production layout, using the production concentration index (PCI). Then, the main factors affecting the PCI of potato were identified, and used to develop an evaluation index system (EIS) for production advantage. Through entropy method, the production advantage of each area in potato cultivation was evaluated, and ranked in descending order. Finally, the priority of each area in potato production layout was measured comprehensively, and a total of 11 areas were determined as priority areas. On this basis, several suggestions were put forward to optimize the production layout of potato in China: (1) The Chinese government should give priority to the following producing areas in the planning of potato production layout: Sichuan, Guizhou, Yunnan, and Chongqing in Northwest China; Gansu, Shaanxi, and Qinghai in Northwest China; Hebei, and Inner Mongolia in North China; Heilongjiang in Northeast China; Hubei in the winter cropping area in the south. (2) The 11 priority areas should arrange potato production as per the local situation, during the planning of crop production layout. (3) The relevant planning departments should grasp the change trend in the producing areas of potato and other water-saving crops, identify their main producing areas, and deploy water-saving crops in dry and water-deficient, which are not suitable for rice or wheat.

1. INTRODUCTION

With the spread of Coronavirus Disease 2019 (COVID-19), some countries have reduced or banned the export of staple food crops. This raises concerns on food security [1, 2]. Being the most populous country in the world, China must give top priority to food security. It is important for the country to improve the overall food yield as per local conditions.

So far, China has basically used up the agricultural lands suitable for rice and wheat [3, 4]. Fortunately, potato, which serves as both staple food and vegetable, could be planted in some dry and water-deficient areas unfit for rice or wheat. Potato boasts advantages of short planting cycle, high yield, and wide adaptability [5], and plays an important role in improving the family income and nutrition of farmers [6]. In 2015, China positioned potato as a staple food. Currently, potation cultivation in China features great potential, wide range, and low yield [7]. Further research is needed to optimize the layout of potation production, and improve its production efficiency and yield.

At present, potato production has been widely studied at home and abroad. But few have attempted to optimize the layout of potato production in China. In terms of production efficiency, Osipov et al. [8] analyzed the efficiency of potato production in Russia, and proved the effectiveness of technical training. Through stochastic frontier analysis (SFA), Kamau et al. [9] examined the technical efficiency and influencing factors of Irish potato production in Monroe County, Kenya. Some scholars [10, 11] conducted data envelopment analysis (DEA) on the efficiency and scale efficiency of potato production.

In terms of storage technology, some scholars [12, 13] explored the effects of different conditions on the anti-browning of fresh-cut potato chips, and concluded that short-term high-oxygen pretreatment and *Portulaca oleracea* extract both have significant anti-browning effects. Lin et al. [14] investigated the cold reaction mechanism of potato tubers stored at low temperature, shedding light on the sugar accumulation and defense reaction of potato tubers under cold storage conditions.

In terms of production layout: Through linear programming optimization, Liu et al. [15] established a national grain production layout optimization model based on the comparative advantage index of agricultural food production (ACI), and achieved the synergy between land, water, and food. Qiao et al. [16] studied the impact of crop distribution and climate change on crop production, using the Environmental Policy Integrated Climate (EPIC) model. Davis et al. [17] derived the potential differences between 14 staple food crops in food production and water use from process-based crop moisture model and spatial interpolated yields, and reduced the water use by optimizing the crop layout. Based on the county statistics in 2000-2003, Yin et al. [18] captured the variation in China's grain production layout in the 21st century. Lv and Sun [19] discovered that potato production in China is more and more accumulated geographically, and gradually shifts from east to west. Yang et al. [20] held that traditional potato production areas, such as the two-season cropping area in the Central Plains, and the one-season cropping area in the north, maintain a large comparative advantage, while the one- and two-season mixed cropping area in the southwest is gaining momentum. The above studies provide a useful reference for this research.

Based on the potato production data of China's 23 provincial administrative regions (hereinafter referred to as provinces) in 2009-2018, this paper calculates the production concentration index (PCI) of potato in each province, and comprehensively evaluates the production advantage of each potato producing area. On this basis, the authors analyzed the priority in the production layout of potato in China, identified the producing area that should be prioritized in production layout. The research results provide insights to the optimization of production layout of potato in China.

2. PCI-BASED PRIORITY ANALYSIS

2.1 Study areas

The one-season cropping area in the north mainly includes Heilongjiang, Jilin, and Liaoning in Northeast China; Shaanxi, Ningxia, Gansu, Qinghai, and Xinjiang in Northwest China; Hebei, Shanxi, and Inner Mongolia in North China. The two-season cropping area in the Central Plains mainly includes Zhejiang, Anhui, and Jiangxi. The one- and two-season mixed cropping area in the southwest mainly include Guizhou, Yunnan, Sichuan, Tibet, and Chongqing. The winter cropping area in the south mainly include Hubei, Hunan, Fujian, Guangdong, and Guangxi.

2.2 Methodology

The PCI, the main index of this research, was defined as the ratio of potato yield in a province to the nationwide yield. The PCI of a province PCI_{it} can be calculated by Eq. (1).

First, the regression equation for the correlation between PCI_{it} and time t was established to analyze the change trend of PCI_{it} in each province. Then, the potato producing areas in China were classified and sorted based on the significance of the correlation.

$$PCI_{it} = \frac{Q_{it}}{\sum_{i=1}^{n} Q_{it}} \times 100 \quad (1)$$

2.3 PCI change trend

Table 1 presents the regression results on the change trend of PCI_{it} in each province. It can be seen that, in 2009-2018, the Chinese provinces differed significantly in the change trend of PCI_{it}.

Based on the significance of the correlation between PCI_{it} and time in 2008-2019, the Chinese provinces were divided into the following characteristic regions of potation production:

(1) Region with significant increase

Seven provinces, namely, Hebei, Shanxi, Guangdong, Sichuan, Guizhou, Tibet, and Shaanxi, saw significant increase in PCI_{it}. The annual PCI_{it} values of these provinces were added up into PCI_1. It can be seen that: the PCI_1 of the region with significance increase rose from 32.75% in 2009 to 43.56% in 2018 (as shown in Table 2); the change trend can be described as: PCI_1=1.466*T+29.078 (R^2=0.922).

(2) Region with significant decrease

Ten provinces, namely, Inner Mongolia, Heilongjiang, Zhejiang, Anhui, Fujian, Hunan, Yunnan, Gansu, Ningxia, and Xinjiang witnessed significant decrease in PCI_{it}. The annual PCI_{it} values of these provinces were added up into PCI_2. The change trend of this region can be expressed as: PCI_2=-1.477*T+52.458 (R^2=0.906).

(3) Other region (region with insignificant change)

Six provinces, namely, Liaoning, Jilin, Hubei, Guangxi, Chongqing, and Qinghai, did not seen any obvious change in PCI_{it}.

Table 2 lists the PCIs of the three characteristic regions in 2009-2018.

Table 1. The change trend of PCI_{it} in Chinese provinces

Province	Regression equation	r	a	Province	Regression equation	r	a
Hebei	PCI_{it}=0.431*T+1.28	0.89	***	Guangxi	PCI_{it}=0.035*T+0.80	0.26	
Shanxi	PCI_{it}=0.135*T+0.98	0.92	***	Chongqing	PCI_{it}=-0.033*T+6.85	-0.34	
Inner Mongolia	PCI_{it}=-0.388*T+11.40	-0.87	***	Sichuan	PCI_{it}=0.300*T+13.38	0.73	**
Liaoning	PCI_{it}=-0.016*T+2.00	-0.17		Guizhou	PCI_{it}=0.475*T+8.84	0.90	***
Jilin	PCI_{it}=-0.087*T+3.21	-0.33		Yunnan	PCI_{it}=-0.193*T+10.20	-0.81	***
Heilongjiang	PCI_{it}=-0.357*T+7.79	-0.85	***	Tibet	PCI_{it}=0.002*T+0.02	0.79	***
Zhejiang	PCI_{it}=-0.039*T+1.37	-0.63	**	Shaanxi	PCI_{it}=0.103*T+3.41	0.85	***
Anhui	PCI_{it}=-0.040*T+0.43	-0.85	***	Gansu	PCI_{it}=-0.204*T+13.16	-0.69	**
Fujian	PCI_{it}=-0.076*T+1.91	-0.78	***	Qinghai	PCI_{it}=-0.045*T+2.28	-0.55	
Hubei	PCI_{it}=0.002*T+3.72	0.03		Ningxia	PCI_{it}=-0.083*T+2.71	-0.94	***
Hunan	PCI_{it}=-0.035*T+2.20	-0.66	**	Xinjiang	PCI_{it}=-0.061*T+1.29	-0.71	**
Guangdong	PCI_{it}=0.020*T+1.17	0.59	*				

Note: r is the correlation coefficient; a is the degree of significance; ***, **, and * are the significance levels of 1%, 5%, and 10%, respectively.

Table 2. The PCIs of the three characteristic regions in 2009-2018

Year	Region with significant increase	Region with significant decrease	Other region	Year	Region with significant increase	Region with significant decrease	Other region
2009	32.75	49.94	17.32	2014	36.93	44.01	18.71
2010	32.27	47.68	20.05	2015	38.53	42.10	19.00
2011	31.99	49.74	18.59	2016	42.71	38.57	17.56
2012	34.21	47.62	17.73	2017	43.18	38.05	17.65
2013	35.28	46.91	17.47	2018	43.56	38.72	16.55

2.4 PCI-based priority

The above analysis shows that PCI_{it} trend differed from province to province, suggesting that the layout of potato producing areas in China changed constantly in the sample period. Then, the 23 provinces were ranked by annual PCI_{it} values in 2009-2018. The rankings of each province in the 10 years were added up into the total ranking score of that province (as shown in Table 3). Next, the provinces with relatively low total ranking scores were given relatively high priority.

As shown in Table 3, the 23 provinces can be ranked by the priority in potation production layout as: Sichuan> Gansu> Guizhou> Inner Mongolia> Yunnan> Chongqing> Heilongjiang> Shaanxi> Hubei> Hebei> Jilin> Ningxia> Qinghai> Hunan> Liaoning> Shanxi> Fujian> Guangdong> Zhejiang> Guangxi> Xinjiang> Anhui> Tibet. The top ranked areas are mostly concentrated in the southwest and northwest, which agrees with the results of Lv Chao et al. (2019).

3. INFLUENCING FACTORS OF PCI

3.1 Variable setting and data description

The PCI_{it} of each province was explained by six variables: the PCI in the previous year, natural disaster, agricultural infrastructure, technological level, industrial structure, and non-agricultural employment. The panel data of the 23 potato producing areas were selected from statistical data like *China Rural Statistical Yearbooks*. The meanings and expected effects of model variables are given in Table 4.

3.2 Model construction

The theoretical model can be established as:

$$\begin{aligned} PCI_{it} &= \alpha + \beta_1 PCI_{it-1} + \beta_2 Disaster_{it} \\ &+ \beta_3 Irrigation_{it} + \beta_4 Techno\log y_{it} \\ &+ \beta_5 Structure_{it} + \beta_6 Nonfarm_{it} + Z_i \delta + U_i + V_{it} \end{aligned} \quad (2)$$

where, i is the serial number of province; t is year; the explained variable PCI_{it} is the PCI of potato production; PCI_{it-1}, $Disaster_{it}$, $Irrigation_{it}$, $Technology_{it}$, $Structure_{it}$, and $Nonfarm_{it}$ are explanatory variables; α is a constant; β_1-β_6 are the coefficients of the six explanatory variables, respectively; Z_i is the time-invariant individual feature; U_i and V_{it} are intercept and disturbance, respectively.

3.3 Results analysis

The model estimation was carried out on StataSE14.0, using short panel data. Through Hausman test, the fixed-effects model was selected for the estimation. The estimation results are recorded in Table 5.

Table 3. The total ranking scores of Chinese provinces

Ranking	Province	2009	2010	2011	2012	2013	2014	2015	2016	2017	2018	Total ranking score
1	Sichuan	1	1	2	1	1	1	1	1	1	1	11
2	Gansu	2	2	1	2	2	2	3	3	3	3	23
3	Guizhou	4	5	4	4	3	3	2	2	2	2	31
4	Inner Mongolia	3	3	3	3	4	5	5	5	5	4	40
5	Yunnan	5	4	5	5	5	4	4	4	4	5	45
6	Chongqing	6	7	7	7	6	6	6	6	6	6	63
7	Heilongjiang	7	6	6	6	7	7	7	9	8	9	72
8	Shaanxi	8	10	9	9	9	8	9	8	9	8	87
9	Hubei	9	9	8	8	8	9	8	10	10	10	89
10	Hebei	15	11	11	11	10	11	10	7	7	7	100
11	Jilin	16	8	10	10	11	10	11	11	11	15	113
12	Ningxia	10	12	12	12	12	12	13	14	14	12	123
13	Qinghai	11	13	14	14	14	15	14	13	15	13	136
14	Hunan	12	14	15	13	13	14	12	16	16	14	139
15	Liaoning	13	15	13	16	17	13	15	15	13	16	146
16	Shanxi	18	18	17	17	16	17	18	12	12	11	156
17	Fujian	14	16	16	15	15	16	16	18	18	18	162
18	Guangdong	20	17	20	18	19	20	20	17	17	17	185
19	Zhejiang	19	20	18	19	19	19	19	19	19	19	190
20	Guangxi	21	21	21	20	18	18	17	20	20	20	196
21	Xinjiang	17	19	19	21	21	21	21	21	21	21	202
22	Anhui	22	22	22	22	22	22	22	22	22	22	220
23	Tibet	23	23	23	23	23	23	23	23	23	23	230

Table 4. The meanings and expected effects of model variables

Variable	Code	Meaning	Expected effect
The PCI in the previous year	PCI_{it-1}	The PCI in year t-1	Positive
Natural disaster	$Disaster_{it}$	Disaster-affected area	Negative
Agricultural infrastructure	$Irrigation_{it}$	Effectively irrigated area	Positive
Technological level	$Technology_{it}$	Potato yield per unit area	Positive
Industrial structure	$Structure_{it}$	Sown area ratio of potato to all crops	Positive
Non-agricultural employment	$Nonfarm_{it}$	Wage income as a proportion of net income of villagers	Negative

Table 5. The estimation results on panel data

Variable	Coefficient	Standard deviation	t-value
The PCI in the previous year	0.3818***	0.05025	7.60
Natural disaster	-0.0046**	0.00178	-2.59
Agricultural infrastructure	0.0103***	0.00323	3.18
Technological level	0.0003***	0.00004	6.71
Industrial structure	10.5795*	5.40432	1.96
Non-agricultural employment	-0.9809	0.9184	-1.07
Constant	0.5688	0.44448	1.28
R^2=0.9296 F-statistic=43.27			

Note: ***, **, and * are the significance levels of 1%, 5%, and 10%, respectively.

As shown in Table 5, our model achieved a good fitting effect. The PCI of potato was significantly promoted by the PCI in the previous year, agricultural infrastructure, technological level, and industrial structure, and significantly suppressed by natural disaster, and non-agricultural employment.

4. PRODUCTION ADVANTAGE-BASED PRIORITY ANALYSIS

4.1 Evaluation index system (EIS) for production advantage

The production advantage of each potato producing area in China was evaluated comprehensively through the entropy method. Drawing on the above results on the factors affecting the PCI, this paper sets up an EIS for production advantage of each potato producing area, which is systematic, effective, and comparable.There are three primary indices in the EIS: technology and facility, nature and economy, and production scale. Each primary index was supported by several secondary indices. Specifically, technology and facility was decomposed into effectively irrigated area (X1) and technical level (X2); nature and economy was decomposed into industrial structure (X3), disaster-affected area (X4), and non-agricultural employment (X5); production scale was decomposed into sown area (X6) and potato yield (X7).

4.2 Comprehensive evaluation of production advantage

Based on the statistics on each potato producing area in 2018, the production advantage of each area was comprehensively evaluated by entropy method. First, the weight of each index was calculated step by step (as shown in Table 6). Then, the comprehensive production advantage scores of the 23 areas were obtained one by one (as shown in Table 7).

Table 6. The entropy, diversity factor, and weight of each index

Index	Entropy	Diversity factor	Weight
X1	0.8839	0.1161	0.1674
X2	0.9125	0.0875	0.1261
X3	0.8512	0.1488	0.2146
X4	0.9787	0.0213	0.0308
X5	0.9676	0.0324	0.0467
X6	0.8500	0.1500	0.2163
X7	0.8627	0.1373	0.1980

Table 7. The comprehensive production advantage scores in 2018

Region		Province	Technology and facility		Nature and economy		Production scale		Comprehensive score	Ranking
			Score	Ranking	Score	Ranking	Score	Ranking		
The one-season cropping area in the north	Northwest China	Shaanxi	0.0111	11	0.0175	6	0.0232	7	0.0519	7
		Gansu	0.0250	2	0.0318	2	0.0478	3	0.1045	3
		Qinghai	0.0086	19	0.0346	1	0.0084	13	0.0515	8
		Ningxia	0.0080	20	0.0215	5	0.0094	12	0.0389	10
		Xinjiang	0.0138	9	0.0052	19	0.0023	21	0.0213	18
	North China	Hebei	0.0214	3	0.0062	15	0.0193	8	0.0468	9
		Shanxi	0.0086	18	0.0108	10	0.0124	11	0.0319	13
		Inner Mongolia	0.0190	4	0.0114	9	0.0323	5	0.0627	5
	Northeast China	Liaoning	0.0099	15	0.0063	14	0.0064	15	0.0227	16
		Jilin	0.0175	6	0.0060	17	0.0063	16	0.0298	14
		Heilongjiang	0.0146	8	0.0067	13	0.0161	10	0.0375	11
The two-season cropping area in the Central Plains		Zhejiang	0.0069	21	0.0051	20	0.0035	20	0.0155	21
		Anhui	0.0028	22	0.0040	23	0.0009	22	0.0077	23
The winter cropping area in the south		Fujian	0.0087	17	0.0087	12	0.0047	18	0.0222	17
		Hubei	0.0103	14	0.0091	11	0.0172	9	0.0365	12
		Hunan	0.0106	13	0.0051	21	0.0075	14	0.0232	15
		Guangdong	0.0094	16	0.0050	22	0.0054	17	0.0199	19
		Guangxi	0.0019	23	0.0060	16	0.0043	19	0.0122	22
The one- and two-season mixed cropping area in the southwest		Chongqing	0.0108	12	0.0229	4	0.0282	6	0.0620	6
		Sichuan	0.0272	1	0.0172	8	0.0613	1	0.1057	2
		Guizhou	0.0188	5	0.0283	3	0.0591	2	0.1062	1
		Yunnan	0.0161	7	0.0172	7	0.0377	4	0.0711	4
		Tibet	0.0125	10	0.0053	18	0.0006	23	0.0184	20

4.3 Production advantage-based priority

The above analysis shows that Guizhou had the highest comprehensive score of production advantage (0.1062), while Anhui had the lowest score (0.0077). Based on the comprehensive evaluation of production advantage, the 23 Chinese provinces can be ranked by the priority in production layout as: Guizhou> Sichuan> Gansu> Yunnan> Inner Mongolia> Chongqing> Shaanxi> Qinghai> Hebei> Ningxia> Heilongjiang> Hubei> Shanxi> Jilin> Hunan> Liaoning> Fujian> Xinjiang> Guangdong> Tibet> Zhejiang> Guangxi> Anhui.

The top-ranking provinces mainly concentrate in Southwest and Northwest China. In Southwest China, Sichuan, Guizhou, and Yunnan ranked high in technology and facility, nature and economy, as well as production scale, a sign of strong comprehensive advantages; Chongqing also had a clear edge in nature and economy, as well as production scale. In Northwest China, Gansu, Shaanxi, Qinghai, and Ningxia boasted strong comprehensive advantages; among them, Gansu ranked in the top 3 in terms of technology and facility, nature and economy, as well as production scale; Shaanxi, Qinghai, and Ningxia ranked among the top in terms of nature and economy.

In North China, Hebei finished the third in technology and facility, which reflects its development advantage; the advantages of Inner Mongolia lay in technology and facility, production scale, and the large area. In Northeast China, Heilongjiang occupied the eighth place in technology and facility, and thus had certain advantages.

5. PRIORITY OF PRODUCTION LAYOUT

5.1 Comprehensive measurement of priority

Drawing on the PCI-based priority and production advantage-based priority, this section comprehensively measures the priority of each potato producing area in production layout. Specifically, the rankings of each province in PCI-based priority and production advantage-based priority were added up, and the provinces with relatively low total ranking score were given relatively high priority. The results of comprehensive measurement are presented in Table 8.

Table 8. The results of comprehensive measurement

Region		Province	PCI-based ranking	Production advantage-based ranking	Total ranking score	Comprehensive ranking
The one-season cropping area in the north	Northwest China	Shaanxi	8	7	15	7
		Gansu	2	3	5	3
		Qinghai	13	8	21	10
		Ningxia	12	10	22	12
		Xinjiang	21	18	39	19
	North China	Hebei	10	9	19	9
		Shanxi	16	13	29	14
		Inner Mongolia	4	5	9	4
	Northeast China	Liaoning	15	16	31	16
		Jilin	11	14	25	13
		Heilongjiang	7	11	18	8
The two-season cropping area in the Central Plains		Zhejiang	19	21	40	20
		Anhui	22	23	45	23
The winter cropping area in the south		Fujian	17	17	34	17
		Hubei	9	12	21	10
		Hunan	14	15	29	14
		Guangdong	18	19	37	18
		Guangxi	20	22	42	21
The one- and two-season mixed cropping area in the southwest		Chongqing	6	6	12	6
		Sichuan	1	2	3	1
		Guizhou	3	1	4	2
		Yunnan	5	4	9	4
		Tibet	23	20	43	22

5.2 Results analysis

As shown in Table 8, the 23 provinces can be ranked by priority of production layout as Sichuan> Guizhou> Gansu> Inner Mongolia = Yunnan> Chongqing> Shaanxi> Heilongjiang> Hebei> Hubei = Qinghai> Ningxia> Jilin> Hunan = Shanxi> Liaoning> Fujian> Guangdong> Xinjiang> Zhejiang> Guangxi> Tibet> Anhui.

Eleven provinces were among the top ten of the comprehensive ranking: Sichuan, Guizhou, Gansu, Inner Mongolia, Yunnan, Chongqing, Shaanxi, Heilongjiang, Hebei, Hubei, and Qinghai. These prioritized areas concentrate in Southwest and Northwest China.

In Southwest China, Sichuan, Guizhou, Yunnan, and Chongqing appeared in the top six whether in the PCI-based ranking or production advantage-based ranking. In Northwest China, Shaanxi, Gansu, and Qinghai were among the top 10 in the comprehensive ranking; Gansu even reached the third place. In addition, Hebei and Inner Mongolia in North China, Heilongjiang in Northeast China, and Hubei in the winter cropping area in the south, also ranked among the top 10 in the comprehensive ranking; these provinces have strong development potential, judging by PCI or production advantage.

6. CONCLUSIONS

Based on the 2009-2018 production data in 23 potato producing areas in China, this paper analyzes the priority of each area in the production layout of potato through PCI trend analysis. In addition, the main factors affecting the PCI of potato were identified, and used to set up an EIS for production advantage. On this basis, the production advantage of each area was evaluated by the entropy method, and ranked in descending order. Finally, the priorities of all the 23 areas in production layout were comprehensively measured, and a total of 11 areas were identified as the priority areas.

In view of the above results, this paper puts forward several suggestions to optimize the production layout of potato in China:

(1) The Chinese government should give priority to the following producing areas in the planning of potato production layout: Sichuan, Guizhou, Yunnan, and Chongqing in Northwest China; Gansu, Shaanxi, and Qinghai in Northwest China; Hebei, and Inner Mongolia in North China; Heilongjiang in Northeast China; Hubei in the winter cropping area in the south.

(2) The 11 priority areas should arrange potato production as per the local situation, during the planning of crop production layout.

(3) The relevant planning departments should grasp the change trend in the producing areas of potato and other water-saving crops, identify their main producing areas, and deploy water-saving crops in dry and water-deficient, which are not suitable for rice or wheat.

ACKNOWLEDGMENT

This work was supported by the Philosophy and Social Sciences Planning Fund, Anhui Province, China (Grant No.: AHSKZ2018D02).

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