

Postprint: Study on Dynamics of Residual Plastic Film in Long-term Mulched Drip-Irrigated Cotton Fields

Authors: He Huaijie, Wang Zhenhua, Zheng Xurong, Zhang Jinzhu, Li Wenhao

Date: 2018-11-08T00:00:00+00:00

Abstract

To investigate the pollution status of residual plastic film in cotton field soils and the distribution trend of residual film in soils under 30 years of mulching, sampling studies were conducted on six cotton fields in the 121st Regiment experimental area with mulching durations of 5, 9, 11, 13, 15, and 19 years. A BP neural network model was constructed using Matlab programs to perform stratified and overall predictions on the sampling data. The results indicate that overall prediction of residual film area and mass data using the model can better reflect the actual distribution trend of residual film in cotton field soils and accurately predict the status of plastic film residues in 30-year mulched cotton fields in this region. Meanwhile, with increasing mulching years, large-area residual film in the soil surface layer fragments annually under tillage operations and migrates to deeper soil layers, accumulating year by year in the 30-40 cm soil depth. The predicted residual film density in 30-year mulched cotton fields reaches $419.19 \text{ kg} \cdot \text{hm}^{-2}$, nearly six times the national standard limit of $75.0 \text{ kg} \cdot \text{hm}^{-2}$. To address this issue, agricultural plastic film with thickness greater than 0.010 mm can be adopted, and the plastic film recycling rate should be improved to ensure sustainable development of cotton fields.

Full Text

Prediction of Residual Film Pollution Trends in Cotton Fields Under Long-Term Mulched Drip Irrigation

HE Huai-jie^{1,2}, **WANG** Zhen-hua^{1,2}, **ZHENG** Xu-rong^{1,2}, **ZHANG** Jin-zhu^{1,2}, **LI** Wen-hao^{1,2}

¹College of Water Conservancy and Architectural Engineering, Shihezi University, Shihezi 832000, Xinjiang, China

²Key Laboratory of Modern Water-saving Irrigation of Xinjiang Corps of Production and Construction, Shihezi University, Shihezi 832000, Xinjiang, China

doi: 10.13866/j.azr.2018.06.27

Abstract

In order to explore the pollution and distribution of residual mulching plastic film in soil in cotton fields over recent 30 years, sample plots in the 121st State Farm of Xinjiang Corps of Production and Construction were selected as the experimental areas, where mulching film was used for 5, 9, 11, 13, 15, and 19 years respectively. The Matlab program was used to develop the BP neural network model for hierarchical prediction and overall prediction of sample data. The results showed that the residual film area and quality data predicted with the model could be used to perfectly reflect the distribution of residual film in soil in cotton fields in recent 30 years. The residual film in topsoil was broken year by year with the time increase of mulching plastic film and moved down to deep soil (30–40 cm). The predicted result revealed that the residual film density in cotton fields would reach $419.19 \text{ kg} \cdot \text{hm}^{-2}$ after mulching plastic film was used for 30 years, which would be nearly 6 times of the national standard limit ($75.0 \text{ kg} \cdot \text{hm}^{-2}$). In order to solve this problem, it is suggested to use the plastic film thicker than 0.010 mm, increase the recovery of mulching plastic film, and ensure the sustainable development of cotton fields.

Keywords: typical oasis; BP Neural Network; cotton field; residual film pollution; residual film density; sustainable development; Shihezi

1. Introduction

Plastic film mulching technology has been widely applied in cotton cultivation in Xinjiang for decades, significantly improving crop yield and water use efficiency. However, long-term application has led to severe residual film pollution in farmland soils. Previous studies have documented that residual plastic film fragments accumulate in soil profiles, affecting soil structure, water infiltration, and crop growth [?, ?, ?]. The residual film density in cotton fields after 30 years of mulching is projected to substantially exceed national environmental standards, posing a critical threat to sustainable agricultural development [?, ?]. This study employs BP neural network modeling to predict the temporal and spatial distribution characteristics of residual film pollution under long-term mulched drip irrigation conditions.

2. Materials and Methods

2.1 Experimental Area and Sampling The experimental area was located at the 121st State Farm of Xinjiang Corps of Production and Construction, with geographical coordinates of 85°01' -86°32' E, 43°27' -45°21' N, and an elevation of 337 m. The region features a typical continental arid climate. Six cotton field plots with different mulching years (5, 9, 11, 13, 15, and 19 years) were selected for soil sampling. Soil samples were collected at 5 cm intervals from 0-40 cm depth using a soil auger. The residual film fragments were separated from soil by water flotation and sieving, then measured for area and mass to calculate film density.

[Figure 1: see original paper]

2.2 BP Neural Network Model Development The BP neural network model was developed using Matlab to predict residual film distribution patterns. The network architecture consisted of four layers: an input layer, two hidden layers with 10 neurons each, and an output layer. The tansig activation function was employed for hidden layers, and the trainlm training function was used for network optimization. Model parameters were set as follows: learning rate (lr) = 0.01, maximum training epochs = 500, and performance goal = 0.001. The model was trained using measured data from different soil depths and mulching years to establish hierarchical and overall prediction frameworks.

[Figure 2: see original paper]

3. Results

3.1 Residual Film Distribution Characteristics The measured data revealed significant accumulation of residual film in the 0-20 cm soil layer, with density decreasing with depth. The hierarchical prediction model accurately captured the vertical distribution pattern, showing that film fragments gradually migrated downward over time. After 19 years of mulching, substantial residual film was detected even in the 30-40 cm layer.

[Figure 3: see original paper]

[Figure 4: see original paper]

[Figure 5: see original paper]

[Figure 6: see original paper]

3.2 Model Validation The comparison between measured and predicted values demonstrated high model accuracy. The predicted residual film density after 30 years of continuous mulching reached $419.19 \text{ kg} \cdot \text{hm}^{-2}$, approximately 6 times the national standard limit of $75.0 \text{ kg} \cdot \text{hm}^{-2}$ [?]. The model effectively simulated the annual fragmentation and downward migration processes of residual film in soil profiles.

[Figure 7: see original paper]

Table 1 Areas and quality of residual film in soil in cotton fields with different film-mulched years

Depth (cm)	5a (v/x)	9a (v/x)	11a (v/x)	13a (v/x)	15a (v/x)	19a (v/x)
0-5	1207.8b/2310.8a	2660.8b/2471.2c	2660.8b/2471.2c	2660.8b/2471.2c	2381.9c/2242.1b	2379.8a
5-10	673.8d/1215.4a	1991.2b/2107.9c	1991.2b/2107.9c	1991.2b/2107.9c	2709.3b/3005.2b	3352.7a
10-15	538.4d/1007.8c	1879.2b/2059.4a	1879.2b/2059.4a	1879.2b/2059.4a	2368.2b/2563.0b	2778.3ab
15-20	315.7d/710.3c	1598.7c/1687.8b	1598.7c/1687.8b	1598.7c/1687.8b	1887.8a/1975.9a	2152.9a
20-25	300.2c/510.7b	1156.7b/1196.7b	1156.7b/1196.7b	1156.7b/1196.7b	1167.9ab/1217.0a	1214.7a
25-30	156.9c/444.0b	932.4b/969.5b	932.4b/969.5b	932.4b/969.5b	905.4ab/1065.2a	1090.3ab
30-35	213.6b/468.3a	458.2b/447.2b	458.2b/447.2b	458.2b/447.2b	494.3b/484.4b	71.8cd
35-40	23.1b/84.5b	36.9ab/170.7a	36.9ab/170.7a	36.9ab/170.7a	228.3b/250.5a	-

Note: $v = \text{area (cm}^2\text{)}$, $x = \text{mass (mg)}$. Different letters indicate significant differences ($P < 0.05$).

4. Discussion

The model predictions indicate that residual film pollution will become increasingly severe without intervention. The fragmentation rate accelerates with mulching duration, leading to exponential accumulation in deep soil layers. Current film thickness standards and recovery practices are insufficient to prevent long-term pollution. The national standard limit of $75.0 \text{ kg} \cdot \text{hm}^{-2}$ [?] will be exceeded within approximately 8–10 years of continuous mulching under current practices.

4.1 Recommendations for Sustainable Management To mitigate residual film pollution, three key measures are proposed: (1) Increase film thickness to 0.010 mm to enhance durability and recovery efficiency; (2) Implement mechanical recovery operations immediately after harvest to maximize collection rates; (3) Develop biodegradable alternatives suitable for arid region conditions. The BP neural network model provides a robust tool for forecasting pollution trends and evaluating remediation strategies.

5. Conclusion

The BP neural network model successfully predicted residual film distribution patterns in cotton fields under long-term mulching. After 30 years, residual film

density is projected to reach $419.19 \text{ kg} \cdot \text{hm}^{-2}$, far exceeding environmental thresholds. Immediate adoption of thicker films and improved recovery technologies is essential for sustainable cotton production in Xinjiang's oasis agroecosystems.

References

- [1] Tian Changyan. Some problems and their scientific and technological countermeasures for sustainable development of cotton production in Xinjiang[J]. *Arid Zone Research*, 2001, 18(4): 62-67.
- [2] Niu Wenquan, Zou Xiaoyang, Liu Jingjing, et al. Effects of residual plastic film mixed in soil on water infiltration, evaporation and its uncertainty analysis[J]. *Transactions of the Chinese Society of Agricultural Engineering*, 2016, 32(14): 110-119.
- [3] Li Xianyue, Shi Haibin, Lv Ye, et al. Effects of different residual plastic film quantities in soil on drip infiltration and its uncertainty analysis[J]. *Transactions of the Chinese Society of Agricultural Engineering*, 2013, 29(8): 84-90.
- [4] O' Loughlin J, Finnan J, McDonnell K. Accelerating early growth in *Miscanthus* with the application of plastic mulch film[J]. *Biomass and Bioenergy*, 2017, 100: 52-61.
- [5] Liu EK, He WQ, Yan CR. 'White revolution' to 'white pollution' – agricultural plastic film mulch in China[J]. *Environmental Research Letters*, 2014, 9(9): 091001.
- [6] Chen Qi' en. Mulching agriculture using thin plastic film in China[J]. *Engineering Science*, 2002, 4(4): 12-15, 21.
- [7] Yan Changrong, Mei Xurong, He Wenqing, et al. Present situation of residue pollution of mulching plastic film and controlling measures[J]. *Transactions of the Chinese Society of Agricultural Engineering*, 2006, 22(11): 269-272.
- [8] He H, Wang Z, Guo L, et al. Distribution characteristics of residual film over a cotton field under long-term film mulching and drip irrigation in an oasis agroecosystem[J]. *Soil and Tillage Research*, 2018, 180: 194-203.
- [9] Shu Fan. The Recycling and Utilization of Agricultural Film and Its Financial Support Policy Research[D]. Beijing: Chinese Academy of Agricultural Sciences, 2014.
- [10] Wang Zhichao, Li Xianyue, Shi Haibin, et al. Study on effect of plastic film residue at different buried depths on silt loam drip infiltration[J]. *Soils*, 2014, 46(4): 710-715.
- [11] Wang J, Lv S, Zhang M, et al. Effects of plastic film residues on occurrence of phthalates and microbial activity in soils[J]. *Chemosphere*, 2016, 151: 171-177.
- [12] Liang Zhihong, Wang Yong. Research summary of damage and control of the remainder of plastic film in farmland in China[J]. *China Cotton*, 2012, 39(1): 3-8.
- [13] Wang Zhenhua. Salt Movement Trends in Cotton Fields with Long-Term

- Drip Irrigation under Mulch in Typical Oasis and Irrigation Management[D]. Beijing: China Agricultural University, 2014.
- [14] Qu Zhongyi, Chen Yaxin, Shi Haibin, et al. Regional groundwater depth forecast by BP model of post-water-saving irrigation[J]. Transactions of the Chinese Society of Agricultural Engineering, 2003, 19(1): 59-62.
- [15] Zhao R, Wang H, Ji T, et al. Biodegradable cationic -poly-L-lysine-conjugated polymeric nanoparticles as a new effective antibacterial agent[J]. Science Bulletin, 2015, 60(2): 216-226.
- [16] Yan Wei, Hu Zhichao, Wu Nu, et al. Parameter optimization and experiment for plastic film transport mechanism of shovel-screen type plastic film residue collector[J]. Transactions of the Chinese Society for Agricultural Machinery, 2017, 47(9): 50-55.
- [17] Zhang Hong, Ma Yan, Li Yong, et al. Rupture energy prediction model for walnut shell breaking based on genetic BP neural network[J]. Transactions of the Chinese Society of Agricultural Engineering, 2014, 30(18): 78-84.
- [18] Qu Ping, Guo Baohua, Wang Haibo, et al. Degradation characteristics of PBAT mulch in maize field[J]. Transactions of the Chinese Society of Agricultural Engineering, 2017, 33(17): 194-199.
- [19] Zhang Jianhua, Qi Lijun, Ji Ronghua, et al. Cotton disease identification based on rough sets and BP neural network[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(7): 161-167.
- [20] Zhang Jia. Cotton disease identification based on BP neural network[J]. Qingdao: Ocean University of China, 2009.
- [21] Wu Xiaoyan, Wang Shu, Zhou Huixing, et al. Design and test of intelligent residual film recovery device based on EtherCAT & GPRS[J]. Transactions of the Chinese Society for Agricultural Machinery, 2016, 47(9): 50-55.
- [22] Yan Changrong, Mei Xurong, He Wenqing, et al. Present situation of residue pollution of mulching plastic film and controlling measures[J]. Transactions of the Chinese Society of Agricultural Engineering, 2006, 22(11): 269-272.
- [23] Yan Wei, Hu Zhichao, Wu Nu, et al. Parameter optimization and experiment for plastic film transport mechanism of shovel-screen type plastic film residue collector[J]. Transactions of the Chinese Society of Agricultural Engineering, 2017, 33(1): 17-24.
- [24] Qu Zhongyi, Chen Yaxin, Shi Haibin, et al. Regional groundwater depth forecast by BP model of post-water-saving irrigation[J]. Transactions of the Chinese Society of Agricultural Engineering, 2003, 19(1): 59-62.
- [25] Wang Guanya. BP Neural Network Algorithm in the Educational Management System to Identify the Direction of Academic Research and Application Trend of Residual Film in Soil in Cotton Field[D]. Beijing: Beijing University of Technology, 2009.
- [26] Zhang Jianhua, Qi Lijun, Ji Ronghua, et al. Cotton disease identification based on rough sets and BP neural network[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(7): 161-167.
- [27] Wang Guanya. BP Neural Network Algorithm in the Educational Management System to Identify the Direction of Academic Research and Application

- Trend of Residual Film in Soil in Cotton Field[D]. Beijing: Beijing University of Technology, 2009.
- [28] The Xinjiang Uyghur Autonomous Region Agricultural and Animal Husbandry Machinery Test and Appraisal Station, The Xinjiang Uyghur Autonomous Region Agricultural Resources and Environmental Protection Station. Limit and Determination of Residual Amount of Farmland Film: GB/T 25413-2010[S]. Beijing: China Standard Press, 2011.
- [29] Zhang Jianhua, Qi Lijun, Ji Ronghua, et al. Cotton disease identification based on rough sets and BP neural network[J]. Transactions of the Chinese Society of Agricultural Engineering, 2012, 28(7): 161-167.
- [30] Zhang Jia. Cotton disease identification based on BP neural network[J]. Qingdao: Ocean University of China, 2009.
- [31] Wang Guanya. BP Neural Network Algorithm in the Educational Management System to Identify the Direction of Academic Research and Application Trend of Residual Film in Soil in Cotton Field[D]. Beijing: Beijing University of Technology, 2009.
- [32] GB/T 25413-2010, Limit and Determination of Residual Amount of Farmland Film[S]. Beijing: China Standard Press, 2011.

Note: Figure translations are in progress. See original paper for figures.

Source: ChinaXiv –Machine translation. Verify with original.