Use of Weather Factors in Clothing Studies in Korea and its Implications: a Review

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Abstract
Climate change-induced weather changes have a sensitive impact on the clothing industry. Developing a predictive model for demand volatility caused by weather changes is necessary to allow a company to generate profit while reducing unnecessary resource use and greenhouse gas and wastewater emissions due to overproduction. This review compares and analyzes empirical clothing research papers published in the Republic of Korea since 2000 and examines research directions on the integration of clothing and weather and how weather information is utilized in the clothing industry. We summarize the impact of temperature, precipitation, wind, humidity, and other weather factors on sales. Specifically, the mixed results published in Korea were compared with previous international studies to find weather data and analysis methods. This study identifies the challenges in weather and sales-related studies and presents the scope of methodological improvements. Furthermore, the role of weather forecasting in the clothing industry’s supply chain is proposed to respond to unpredictable weather patterns caused by climate change. The results of this review study should be considered that there is a limit to analyzing clothing sales in Korea only with weather factors because consumers’ purchasing motives are very diverse.

Keywords Climate change · Weather · Effect of weather change · Weather dependent clothing sales

1 Introduction
Climate change can affect our society by impacting various social, cultural, and natural resources. Moreover, it affects these resources, the goods and services they produce, and their consumption. In many environmental studies, climate change-induced weather changes have been scientifically proven, providing a wealth of information. However, it remains to be seen how climate change-induced weather change information will prevent industry losses and generate profits. In particular, the clothing industry is recognized as being subject to significant financial fluctuations due to weather changes (Agnew and Palutikof 1999; Bertrand et al. 2015; Bertrand and Parnaudeau, 2019; Changnon 1999; Oh and Jo 2011), but there is a lack of strategies for effectively incorporating weather information in business plans.

As the climate changes-induced weather changes, demand fluctuates, known as demand volatility. For example, severe drought and weather pattern changes may cause a shortage of cotton. It may increase the cost of a cotton t-shirt, and thus the price of a cotton t-shirt is increased. The clothing price could drive consumers to purchase alternative t-shirts such as polyester blended cotton t-shirts instead of 100% cotton t-shirts. As another example, as the temperatures rise abnormally in winter, demand for a winter jacket and gear declines. Unexpected weather events can potentially disrupt a company’s supply chain, getting the resources and materials and causing them financial loss.

The primary purpose of clothing is to keep humans warm and protect them from the environment. Over time, clothing began to serve other purposes, symbolizing status, gender, and wealth. In the 2000s, many mass-production fashion companies adopted fast fashion as a business model, reducing
the purchasing cycle and lead time needed to bring new products into stores with the highest consumer demand (Ciarniene and Vienazinadiene, 2014). The fast-fashion business model has become dominant, and its rapid fashion cycle induces consumers to purchase more than they need. This cycle leads to increased clothing waste, similar to trends observed with the growth of fast food (Nature Climate Change, 2018). The number of people wearing a single piece of clothing has decreased by 30% over the past 15 years (Ellen MacArthur Foundation 2017). Clothing consumption in Korea increased at an average annual rate of 3.7%, from $34.5 billion in 2005 to $55.5 billion in 2018. As of 2020, the clothing industry, which is currently worth $1.5 trillion globally, is a large-scale industry that surpasses that of passenger cars, home appliances, computers, and telecommunications devices, and consumes more energy than other large industries. Specifically, it emits 10% of the world’s greenhouse gases, making it a higher emitter than all international flights and maritime shipping combined (McKinsey & Company 2020).

Most fashion companies predict demand by synthesizing information on the market economy, politics, and culture with sales data from the previous year (Brannon and Divita 2015). However, climate change due to the influence of greenhouse gases frequently causes unpredictable and anomalous weather events. As the intensity of these fluctuations increases, many companies have begun to suffer losses due to an imbalance between supply and demand (Bertrand et al. 2015). Because the supply chain comprises many industries, such as fiber producers, textile producers, clothing manufacturers, and retailers, it takes up to two years to go through various processes (Stone 2012). In particular, in the case that production sites for each operation are spread across several countries, launching a product with a short lifespan and seasonality to meet demand is not simple. In Korea’s clothing industry, the proportion of overseas production is high, and most small-scale establishments employ less than ten employees (Korea Federation of Textile Industries 2020). It is impossible to respond quickly and flexibly to sudden changes in weather factors.

Figure 1 shows the circular relationship among climate, weather, clothing supply chain, and consumer. Climate change-induced weather change disrupts the balance of supply and demand. Clothing is launched to the store according to predicted weather, typical retail calendars, and last year’s sales patterns. However, rapid weather changes caused by climate change affect consumers’ purchasing decisions and consumption, so the timing and quantity of
demand deviate from the supplier’s forecast. If the timing and amount of consumer demand deviate from the plan, the company loses capital and discards and incinerates unsold products, thereby emitting greenhouse gases. The emitted greenhouse gas accelerates climate change and further disrupts the balance between supply and demand. It is important to transform the clothing industry into an eco-friendly and low-carbon, even zero-carbon sector by developing a predictive model to prevent greenhouse gases, wastewater, and unnecessary resources emitted by overproduction due to demand fluctuations caused by climate change.

Despite the many environmental studies that provide data on weather patterns due to climate change, it is unclear how information about weather changes can generate profits. Therefore, this study is meaningful in suggesting the applicability of weather information to the clothing industry, experiencing difficulties in supply chain management due to sudden weather changes. The purpose of this review study is to find a way to use weather information that can maximize the profits of the clothing industry without wasting resources through a comparative analysis of empirical research papers published in Korea. Using DBpia (https://www.dbpia.co.kr/) and Google Scholar (https://scholar.google.com/), we searched for publications published from January 2000 to September 2021 that included the following keywords in the abstract, keywords, and subject terms: weather, weather change, climate, climate change, meteorology, clothing, fashion, clothes, apparel, sales, and demand. This search yielded 15 empirical research papers that utilized weather information to investigate the relationship between weather and clothing sales and predict sales with weather factors. Based on these 15 published papers, the relationship between weather factors and sales was summarized and presented, and the results were compared with existing international studies to examine whether the research results were consistent and the causes of differences. In particular, we review how weather factors are used and analyzed in clothing sales by considering data collection, analysis methods, and results among the research methods of published studies and propose a method to utilize weather information in the clothing supply chain.

2 Clothing Industry Characteristics and their Relation to Weather Pattern Changes

2.1 Global Industry

The clothing industry has continuously aimed for low cost and flexibility in design and quality and accelerated the market through constant innovation and adaptation to new technologies. In general, this industry is characterized by short-lifespan products, high volatility, low predictability, and high impulse purchases (Christopher et al. 2004). The traditional protocol is managed by a fixed calendar of trade shows and market weeks, consisting of a two-season approach to product ranges, such as S/S and F/W (Stone 2012). It consists of numerous sub-industries that strive to satisfy consumers, and the clothing supply chain leading to the new season spans nearly 24 months. Decision-making changes are complex and time-consuming, given the supply chain, from fiber and textile production to retail, across multiple regions or countries.

The clothing industry is highly sensitive to weather changes (Agnew and Palutikof 1999), and the supply chain is scattered and multi-layered globally, making it difficult to change plans in the middle of the season. Long lead times and low flexibility lead to over- and understocking problems (Agnew and Thornes 1995). In specific scenarios, lead time can be extended compared to the sales season, and consumer demand can change rapidly depending on the trend, taste, season, and situation. Understock leads to a loss of potential sales opportunities due to a surge in demand when the product is not ready for sale, thus damaging the brand image by failing to meet customer needs. Therefore, the clothing industry requires accurate evaluations of product stocking ahead of sales seasons and dates. Overstock creates a series of problems, including space management and out of fashion to liquidity issues. Price cuts and promotional events are necessary to improve a given company’s cash flows.

If the supply chain fails to respond quickly to erroneous demand forecasting and sudden changes in demand, a cycle continues in which climate change factors, such as resource waste, greenhouse gas emissions, and water pollution, culminate to induce more severe issues. In the worst, highly unethical cases, fashion brands destroy unsold products to prevent the loss of brand value and preserve product value following oversupply. For example, Burberry, a British luxury brand, destroyed $378 million in products in 2017/18 (Women’s Wear Daily 2019). Similarly, the low-price brand H&M burned 60 tons of unsold products (BBC News 2018).

2.2 Korean Industry

The Korean clothing industry creates large-scale employment, and the domestic market size reached $55.5 billion (13.1% of the total domestic demand) as of 2018 (Park, 2019). However, due to persistent company shrinkage and an aging workforce, the production base is weakened, and profitability and productivity are low. Compared to developing countries such as China and Vietnam, price competitiveness is lower, and in developed countries such
as Italy and Japan, the brand image and design are inferior (Park 2019). Furthermore, it is reversing the production of companies that have moved their production bases overseas. The trade deficit is widening because of the increase in imports of high-end luxury brand clothes. The global market share of the domestic clothing industry fell from 5.0% (5th place) in 2000 to 2.2% (12th place) in 2010 and then fell sharply to 1.7% (16th place) as of 2019 (Park 2020). The mid-priced market has shrunk, and low-priced global fast fashion brands and high-priced overseas brands have eroded the market (Korea Eximbank Overseas Economic Research Institutes 2017).

Demand volatility is high, and even for products with the same designs, demand differs across size and color, making it difficult to accurately predict demand. If a product cannot be produced and sold on time due to its short lifespan, the inventory value plummets and profitability deteriorates. Domestic brands take six months from product planning to sales, and cooperation with companies in related fields is vital for the efficient procurement and production of raw and subsidiary materials. Furthermore, the Korean clothing industry is one of the industries that suffered the most from the COVID-19 crisis, and thus, most products remain stocked because those from canceled orders cannot be sold (Chung 2020).

The clothing industry in Korea has established a strategy to transform itself into a leading national industry on the global stage, illustrated by the keywords of “green,” “digital,” “safety,” and “cooperation,” to strengthen international competitiveness through technological innovation. This approach aims to meet these objectives by 2025, as outlined in the goals of the Korean New Deal (Korea Federation of Textile Industries 2020). In particular, the clothing industry aims to incorporate eco-friendly material development, resource circulation systems, and green fiber ecosystem promotion as an action strategy to implement the UN Climate Convention agreement and achieve zero emissions by 2050 (United Nations Framework Convention on Climate Change 2018).

### 2.3 Relationship between the Clothing Industry and Weather Pattern Changes

Climate change often causes unpredictable weather events and increases in intensity, causing losses to many fashion companies due to imbalances in supply and demand (Bertrand et al. 2015). There is significant evidence that the fashion industry is struggling with unseasonal weather. Record El Niño events marked the winter of 1997–1998, and retailers in the northern states of the United States struggled with a shortage of winter clothing sales (Changnon 1999; Oh and Jo 2011). The winter of 2015 was unseasonably warm in the northeastern United States, with winter temperatures reaching 16 °C above average. Major US fashion companies could not foresee these extreme events and suffered significant economic losses (New York Times 2015). The average temperature in November 2015 in Korea was 10.1 °C, which was 2.5 °C higher than the climate normal temperature (7.6 °C). As a result, winter clothing sales decreased by 18.1% compared to the previous year (Hankyoreh 2015).

Although many experts acknowledge the importance of weather as a sales predictor, few companies use weather information in their merchandising initiatives. The business plan has been developed expecting that “super normal weather,” warmer than usual S/S and cooler than usual F/W, will occur annually (Petty 1963). Zara, the largest fast fashion retailer globally, has recently adopted a new operating strategy to increase agility and flexibility while quickly responding to external changes such as those in weather (Schlossberg 2016). Because Zara has a manufacturer close to the headquarter, it responds to sudden changes, such as unseasonable weather changes. If we consider supply chains that include upstream yarn and fabric producers and downstream retailers, the changes in product assortment planning are not simple.

Black Yak, a Korean outdoor clothing brand, uses real-time information-sharing systems both inside and outside physical stores. By incorporating weather information, the visual merchandiser can change displayed clothes to present the best style for the weather, thus contributing to a 30% increase in sales by implementing weather information. Another brand has benefited from predicting monsoons and heatwaves in 2013: SPRIS, a footwear brand, has arranged summer sandals intensively in 150 stores nationwide from the end of May, selling more than double compared to the previous year’s same period (Maeil Business News Korea 2013). As an example of planning product procurement using AI-based short-term weather forecasts, Lotte Home Shopping plans fashion products using the national 30-day weather forecast and the local 6-month weather forecast (Maeil Business News Korea 2020). Although it is critical to lay the foundation for a demand forecast model that responds to climate change from a business perspective, many companies struggle to understand and adapt to unpredictable weather beyond their control. Linking optimal clothing items to current weather conditions is not a simple matter.

### 3 Utilization of Weather Information in Clothing Studies

Many meteorologists and economists recognize that unexpected weather causes financial losses related to primary, secondary, and tertiary industries, such as tourism and retail (Bertrand and Parnaudeau 2019; Brown et al. 2019; Changnon 1999; Miller 2009; Ministry of Environment
Ex tant literature provides a relatively minimal understanding of consumers’ responses to weather, and little attention has been given to the subject in social science research, particularly clothing studies.

This study extracted and analyzed empirical clothing studies published in DBpia and Google Scholar since 2000 using the method specified in the Introduction. Table 1 summarizes empirical studies on weather effects on clothing sales. Previous researchers investigated the relationship between weather factors and clothing sales using daily weather data and daily/monthly/quarterly sales data. Various clothing products were studied according to season, gender, age, use, and function, and a study by Lee et al. (2010) investigated the importance of weather information to department store managers through a survey. Also, most of the studies studied the sales of brick-and-mortar stores, and Hong (2019) conducted online store sales with weather factors.

Figure 2 shows the numbers of times each weather factor used in Korea’s clothing studies published from January 2000 to September 2021. Temperature and precipitation are the most used weather factors. Temperature data included maximum, minimum, and average, and precipitation data include rainfall and snowfall. Humidity, wind speed, sunshine, sea level pressure, and cloud cover data were used. Furthermore, some studies employed fine dust, weather condition (e.g., clear, cloudy, rainy/snowy), and disaster data. Based on the results of previous studies, the effects of weather factors on clothing sales are summarized in Fig. 3. Next, the relationship between weather factors and sales of specific weather factors is discussed below.

### 3.1 Temperature

Because most clothing items are seasonal, we expected warmer temperatures to increase sales of S/S products and decrease sales of F/W products. Most previous studies have demonstrated this relationship (Back et al. 2019; Han 2021; Hong 2019; Hong and Lee 2013; Hong et al. 2012; Hwangbo et al. 2017; Jang and Lee 2002; Jang and Lim 2003; Kim et al. 2017; Lee et al. 2010; Lee et al. 2011; Lim and Lho 2018; Oh et al. 2017), but temperature changes were found to be insignificant within a certain period. Lim and Lho (2018) found that sales increase with temperature differences, but the more significant the temperature change to some extent, the less impact they have on sales. In addition, they showed that an increase in consumer purchases tended to complete purchases before the seasons changed. Oh et al. (2017) used the 7-day moving average of temperature data instead of daily average temperature data for analysis. From this data, they posit that rather than daily temperature change, low pressure, high pressure, cold waves, heat waves, and similar climate factors, changes in temperature over a period make consumers feel the need to purchase seasonal clothing. The 7-day moving average temperature, the start date, growth season, peak season, decline season, and end date of spring clothing sales were used as reference temperatures. They showed that the decline period of the S/S clothing season began in August at the high point of the 7-day moving average temperature value.

The above studies confirmed that although temperature changes are an important factor in predicting sales, there is no relationship between temperature change and sales after a certain period. International studies also confirmed the above results (Agnew and Palutikof 1999; Arunraj and Ahrens 2016; Bahng and Kincade 2012; Bertrand et al. 2015). The end of a season is the beginning of a new season, and consumers want to buy new season clothes. Therefore, the temperature changes are an essential variable in predicting seasonal clothing sales at the beginning of the season but are less effective at the end of the season.

### 3.2 Precipitation

Precipitation includes rainfall and snowfall, and studies have shown the effectiveness of precipitation on sales (Chu et al. 2013; Hong et al. 2012; Hong and Lee 2013; Jang and Lee 2002; Jang and Lim 2003; Lee et al. 2010; Lee et al. 2014). In general, precipitation had a negative effect on brick-and-mortar store sales, depending on the region or the type of location where the store is located. It creates unfavorable weather conditions that make consumers feel physically and psychologically uncomfortable when going to a store. Significantly, one study found that department store managers considered precipitation to be the most sensitive weather factor affecting sales (Lee et al. 2010). The results of the above studies are supported by previous research. Namely, store traffic on rainy days was reduced by 7.4% in street stores (Martinez-de-Albeniz and BelKaid 2021), and for areas in which snowfall is historically uncommon, an inch of snowfall reduced sales by 17% (Tran 2019).

### 3.3 Wind Speed

Wind speed contributes to human comfort and affects consumer behavior. The effect of wind speed on clothing sales was investigated, but the results were inconsistent. Several studies found that wind speed did not affect sales (Hong et al. 2012; Kim et al. 2017; Lee et al. 2011), whereas Han (2021) found that wind speed has a minimal effect on sales. Moreover, Jang and Lee (2002) and Hong and Lee (2013) found a partial effect. There were no consistent effects of wind speed on sales. Only one study found that wind speed affected women’s clothing sales during the four seasons.
| Sources                                      | Variables                                                                 | Weather Factor                                                                 | Findings                                                                                                                                                                                                                                                                                                                                 |
|----------------------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------|----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| Han (2021)                                   | Daily sales of women’s golf wear over 3 years                              | Temperature, precipitation, wind speed, humidity, snow depth                    | Humidity and minimum temperature in spring, humidity in summer, and average temperature and minimum temperature in autumn are essential variables that affect sales.                                                                                                                                                                                                                     |
| Back, Oh, Lee, Hong, & Hong (2019)           | Daily tops sales from an online clothing store from 2014 to 2017           | Temperature                                                                     | Sales of short-sleeved tops increase when temperature increase; Sales of long-sleeved tops decrease when temperature increase.                                                                                                                                                                                                                                                             |
| Hong (2019)                                  | Daily sales from online a clothing store for 5 years                      | Temperature                                                                     | For accessories for winter, sales increased when the temperature decreased, and for short-sleeved t-shirts and shorts, sales increased when the temperature rose.                                                                                                                                                                                                                                           |
| Lim & Lho (2018)                             | Quarterly sales of 6 fashion companies                                    | Temperature difference (Heating and cooling day), precipitation, humidity, four seasons | Sales increase according to the temperature difference, but sales increase with temperature changes, the more significant the temperature change to some extent, the less impact they have on sales. Consumers purchase before the season’s change.                                                                                                                                                                                                                                                                 |
| Kim, Hwangbo, & Chae (2017)                  | Daily sales volume of F/W lines from men’s wear and sportswear brands in a company for 4 years | Temperature, wind speed, humidity, rainfall, fine dust, sea level pressure sunshine | The concentration of fine dust had the most significant influence. As the average temperature decreased, fall/winter product sales increased, and humidity, sea level pressure, and sunlight were partially affected.                                                                                                                                                                                                                          |
| Oh, Oh, & Choi (2017)                        | Daily sales of S/S lines in 2013 from a national brand                   | Temperature                                                                     | Sales of seasonal products grow when the 7-day moving average temperature is above 4 °C, and peak season is from 17 °C to the highest point. After that, there is a downward trend, and the sale ends when the temperature drops below 21 °C.                                                                                                                                                                                                                     |
| Hwangbo, Kim, & Chae (2017)                  | Daily sales data during 2015 – 2016 from casual brands and outdoor brands in a national clothing company | Average temperature, rainfall, sea level pressure fine dust,                   | In casual brands, the average temperature had an influence on the sales volume of spring/summer products, and the sea level pressure affected the sales volume of summer/fall/winter products. In outdoor brands, the average temperature and the fine dust significantly influenced the sales volume of all season’s products. The sea level pressure affected the sales volume of summer/fall/winter products.                                                                                                                                 |
| Sources                         | Variables                                                                 | Weather Factor                                                                 | Findings                                                   |
|--------------------------------|---------------------------------------------------------------------------|--------------------------------------------------------------------------------|------------------------------------------------------------|
| Lee, Kwak, Hwang (2014)        | Daily sales data from a footwear brand for 5 years                         | Precipitation                                                                  | Precipitation affected sales of S/S products.             |
| Chu, Kim, & Choi (2013)        | Daily sales data of an outdoor clothing brand from July to September for 3 years | Rainfall                                                                       | Rainfall had a negative effect on sales depending on the region or the type of location where the store is located. |
| Hong & Lee (2013)              | Six items of daily sales data from a clothing store in Seoul for 5½ years. | Temperature, precipitation, wind speed, snow depth                               | Precipitation and wind speed for spring/summer long-sleeve shirts and temperature and snowfall for autumn/winter long-sleeved shirts affected sales. Sales of winter jackets were affected by the temperature. |
| Hong, Lee, & Na (2012)         | Daily sales data of a large discount store for 2 years                     | Temperature, wind speed, humidity, rainfall, cloud cover snowfall               | When the temperature rises, sales of summer products increase; when the temperature decreases, sales of winter products increase. Swimsuits are related to precipitation, and winter mufflers are related to snowfall. |
| Lee, Ahn, & Chung (2011)       | Daily sales data of casual, women’s, men’s wear in six major cities for 1 year | Temperature, precipitation, wind speed, relative humidity, sunshine cloud cover snowfall weather conditions (clear, cloudy, rainy, & snowy) | There is no difference in sales depending on the weather conditions in casual and women’s wear’s sales, whereas there was a difference in sales of men’s wear depending on the weather conditions. According to the season, temperature and humidity were different for casual, women’s, and men’s wear. |
| Lee, Ko, & Jeon (2010)         | Store manager’s perception of weather factors on sales                     | Maximum, minimum, & average temperature, precipitation, disaster (yellow dust, typhoon, flood, snowstorm) | Department store managers considered precipitation, disasters, and then temperature to affect sales. |
| Jang & Lim (2003)              | Men’s and women’s wear in a department store sales data for 3 years       | Temperature, precipitation, average wind speed                                  | In women’s clothing sales, wind speed affected all seasons, and precipitation had a negative impact on spring and summer. Designer boutiques and unisex casuals were not affected by the weather, and young casuals were affected by the weather. |
| Jang & Lee (2002)              | Department store sales data in women’s wear, men’s wear, children’s wear, golf wear, activewear, and lingerie for 3 years. | Temperature, precipitation, average wind speed, sunshine                        | Temperature and precipitation affected sales, and sunlight and wind speed partially affected sales. The effect was different for each type of clothing. |
The sales of women's wear increased in the spring when the wind speed increased, and when the wind increased in autumn and winter, the sales of women's wear decreased. This result is contrary to the common results. Commonly, wind speed improves the thermal environment and contributes to the level of human comfort. In cold weather, winds lead to lower felt temperatures. The wind chill equivalent temperature is used to provide a more meaningful description of human perception of cold rather than the air temperature. In a hot and humid climate, wind helps lower temperatures and increases comfort (Hoppe 1999; Huang et al. 2020; Rijal 2012). These inconsistent results have also been found in international studies. Specifically, studies have investigated the effect of wind speed on clothing buying behavior, but no significant correlative results were observed (Badorf and Hoberg 2020; Martinez-de-Albeniz and BelKaid, 2021).

3.4 Humidity

Humidity and temperature change vary in summer Korea, and thus it is meaningful to examine whether humidity affects clothing sales. Several scholars have studied the effect of clothing type and seasonal humidity on sales (Han 2021; Hong et al. 2012; Kim et al. 2017; Lee et al. 2011; Lim and Lho 2018). Women's wear was affected by humidity in spring, fall, and winter; men's wear was affected by humidity in fall and winter; and casual clothes were affected by humidity in spring (Lee et al. 2011). Another study investigated the relationship between F/W products and weather (Kim et al. 2017). The sales of men's wear, casual clothes, wear, and tops increased as the humidity increased. Han (2021) studied golf wear sales by season, and the humidity affected spring and summer sales, but the relationship with humidity had a curved relationship with temperature and
interaction. The effectiveness of humidity on clothing sales has been confirmed by other scholars (Arunraj and Ahrens 2016; Badorf and Hoberg 2020; Bertrand and Parnaudeau 2019; Martínez-de-Albeniz and BelKaid, 2021), but the nonlinear effects require further investigation. Based on previous findings, we may conclude that there is an interaction between humidity and temperature. Humidity is impacted differently by season and clothing type, but high humidity negatively affects the sales of all types of clothing in summer. This conclusion can be explained by the heat discomfort index. It combines temperature with humidity to determine what the air temperature feels like to the average person for various combinations of temperature and humidity (Ahrens and Henson 2016). It assesses the impact of heat stress on the individual and considers temperature, humidity, or a combination of these factors. When the temperature is high and the humidity is low, the sweat formed on the skin evaporates quickly, giving the impression of a lower outdoor temperature.

3.5 Other Weather Factors

Hwangbo et al. (2017) investigated the effects of weather factors on casual wear and outdoor wear sales. Their study included sunshine, sea level pressure, and fine dust. Fine dust from weather factors is the most essential factor for clothing sales. The lower the concentration of fine dust, the higher the sales. This was supported by a study on the sales of F/W clothing (Kim et al. 2017). To the best of our knowledge, studies on fine dust and clothing sales have not been conducted. As interest and concerns about fine dust concentration increase, Korean consumers refrain from outdoor activities on days when the concentration is high (Lee et al. 2020). It can be inferred that the concentration of fine dust affects sales.

In the case of sea-level pressure on sales, Hwangbo et al. (2017) found that the lower the sea level pressure, the higher the summer clothing sales, and the higher the sea level pressure, the higher the winter clothing sales. They concluded that summer clothing sales increased because summer tends to be hot due to clear weather. When the weather is clear during winter and fall, people are more likely to go out and shop, and thus winter clothing sales are increased. However, in summer, the humidity is high when sea level pressure is low. It is difficult to draw conclusions without testing the interaction of sea level pressure, temperature, and humidity. Another study found that inconsistent association between sea level pressure and sales depending on types of clothing such as formal wear, casual wear, and sportswear (Kim et al. 2017). The duration of sunlight was not constant in clothing sales, and the effects were different depending on the season and product category (Jang and Lee 2002). This result was supported by other international studies (Arunraj and Ahrens 2016; Badorf and Hoberg, 2020). Lee et al. (2011) studied the effects of weather conditions, such as clear, cloudy, rainy, and snowy, on clothing sales in department stores. Casual and women’s wear were not affected by the weather. However, in the case of men’s wear, sales on clear days were higher than on cloudy, rainy, and snowy days. In a study based on a survey on the perception of weather conditions of department store managers, localized heavy rains were found to have the most significant effect on sales among weather disasters (Lee et al. 2010).

4 Conclusion

As we experience new weather patterns, increased temperature and precipitation variability, and increased rates of extreme weather events (Kassam et al. 2018; Min et al. 2015; Thorton et al. 2014), the reliability of current sales forecasting methods should be re-examined. The purpose of this review is to reconsider the direction of research on the integration of clothing and weather and the method of using weather information in the clothing industry by examining the relationship between sales and weather and prediction methods published in clothing research since the 2000s. As a highly weather-sensitive industry, the clothing industry must prepare for demand volatility due to climate change-induced weather changes and develop predictive models that allow businesses to generate profit while reducing unnecessary resource use and greenhouse gas and wastewater emissions due to overproduction. Because the industry is dominated by fast fashion, the fashion cycle is rapid, causing consumers to buy more clothing than they need. Moreover, most companies have a highly fragmented global value chain that includes fiber producers, textile producers, manufacturers, and retailers requiring long lead times that impair the ability of these companies to meet rapid demand fluctuations. The following is a summary of the existing studies and suggests problems to be solved in future studies.

First, after a study in the 1950s (Steele 1951), snow and rain had a negative effect on clothing sales by creating inconvenience and unfavorable weather for shopping trips. In 2020, non-store retail sales increased 24.2% to $90 billion, more than double that of large marts $30.7 billion (4.2%) and department stores $25 billion (9.9%). As a result, non-store retailing has become a major distribution channel (Korea Federation of Textile Industries 2021). As some consumers purchase clothing at non-store retailers, it remains necessary to re-examine whether precipitation makes shopping uncomfortable and affects sales. Although non-store retailing, such as online and TV home shopping networks, comprises a viral buying channel, brick-and-mortar stores still serve a key social and economic function in local communities. In addition, as weather affects consumer mood...
(Murray et al. 2010), weather can affect sales, so the psychological factors of consumers shopping at brick-and-mortar and non-store retailers along with weather should be studied together.

Second, humans feel weather changes by combining various factors, not just one weather factor. The sensation of heat or cold depends on variables other than the measured temperature. For example, two well-known indices are the Windchill and Heat Index, and these indices are used with temperature when the media provides weather information (Yan and Oliver 1996). In addition, because humans inhabit various cultures and environments, they exhibit different physical and psychological evaluations of weather despite similar climatic conditions (Kenz and Throsson, 2016; Kim and Park 2014). Thus, a demand forecasting model based on the weather changes experienced by consumers should be developed.

Third, a method of comparing the daily weather and sales and examining the relationship between a piece of single weather information and sales has limitations in predicting sales in the clothing industry. Few studies mention lags between weather changes and sales (Agnew and Palutikof 1999; Arunraj and Ahrens 2016), but these studies did not provide empirical results. Instead of daily weather changes and sales, Oh et al. (2017) considered the tendency of temperature change due to the influence of longitudinal weather events such as low pressure and high pressure by averaging the temperature change according to the effect of longitudinal weather events. Oh et al. (2021) studied the effect of anomalous weather on the seasonal clothing market in New York as a place-specific case study. They provided a methodology to discover the time lag for seasonal clothing demand timing based on temperature changes. A method for developing an optimal demand forecasting model using various analysis methods for changing weather and the decision-making process executed by consumers using this information should be studied.

The clothing industry requires timely and accurate weather information to improve the managerial implications of the supply chain. Since the 1950s, companies have recognized that early weather changes in each new season are significant because rapid weather changes have increased the sales of new seasonal clothing (Steele, 1951). The critical point is how quickly a company obtains accurate weather information and uses this data for planning, production, and distribution. According to the National Institute of Meteorological Sciences (2021), the average annual temperature in Korea is expected to rise by 2.2–7.0 °C from the present, depending on greenhouse gas emissions, precipitation levels, and precipitation days. Data on temperature extremes in Korea show long-term warming trends with frequent warm events and low-frequency cold events, along with significant interannual and decadal fluctuations (Min et al. 2015). Yet unexperienced patterns of extreme weather events may emerge in the near future. In this case, potential preparation approaches for the Korean clothing industry must be identified. To cope with rapid changes, weather information should be actively used, and clothing products suitable for new climate and weather conditions should be developed for consumers.

Finally, based on the conclusions of the studies reviewed above, this study proposes the types of weather forecasts according to the time required for the clothing supply chain and how to use the weather information and summarizes it in Fig. 4. Fiber and textile producers consist of growers and producers of raw materials, such as fiber, fabric, leather, and fur. Most fiber and textile producers are farms and chemical factories. Color and texture decisions occur at this stage as the earliest part of the planning function. Because a lead time of up to 24 months is needed by producers before clothing products can be available to the consumer, fiber and textile producers require bi-annual, annual, and inter-annual forecasts to provide appropriately priced and suitable materials to manufacturers. If accurate weather information is provided, fiber producers and textile manufacturers can profit by supplying an appropriate amount without wasting resources or polluting the environment.

Clothing manufacturers are designers and manufacturers who produce clothing from the materials produced by fiber and textile producers. They work from six months to one year ahead of time that the finished product is available to consumers. Inter-annual and seasonal forecasts allow designers and manufacturers to create seasonal product lines suitable for weather outlook in the coming season. In the retail stage, is the ultimate distribution stage. The different types of retailers buy their products from manufacturers and then supply them to the consumer. Clothing buyers and retailers procure products and make an initial merchandising plan with a seasonal weather outlook. After a season begins, clothing buyers and retailers may negotiate product launch timing and adjust their order of products based on a monthly forecast. An 8–14 day short-term forecast helps retailers determine logistic, promotion, and pricing strategies according to weather changes in the middle of the season. In addition, nowcasting can help brick-and-mortar stores’ and online stores’ promotional events. Depending on the daily weather conditions, retailers adapt managerial implications to increase inventory turnover and improve cash flow. Up to now, seasonal and long-term forecasts are inaccurate, and seasonal and long-term forecasts provide more reliable weather trends than absolute weather information. However, the clothing industry should regularly respond to weather changes because it creates enormous business decision-making tasks. Through resilience management, information available should be quickly integrated to make informed decisions at each stage in the supply chain. Decisions should
be updated when new information is provided. Moreover, technologies in the clothing industry have been improving to reduce lead times.

Weather changes encourage consumers to consider purchasing new clothing. Consumers obtain nowcasting and short-term weather information from the media as well as the physical experience of daily weather. This recognition of weather changes leads consumers to search for information on new clothing. Although weather changes are part of buying motivation, it influences consumers’ everyday clothing choices. The consumer buying cycle is directly related to the consumer use cycle. However, unexpected weather changes occur during this cycle. Although empirical research has not yet been conducted on the disconnection of cycles due to weather changes, it hurts the entire clothing supply chain. In addition, unsold items become trash and waste all resources, including raw materials, energy, water, chemicals, and human labor. If the supply chain fails to respond quickly to erroneous demand forecasting and sudden changes in demand, a vicious cycle continues to increase factors that cause climate change, such as resource waste, greenhouse gas emissions, and water pollution.

This study analyzed only studies published after 2000 in Korea. There are 15 papers valid for the selection criteria, which is insufficient to draw an overall conclusion. Also, it is insufficient to extend the results of this paper to other climatic zones or regions. Since the types of clothes and the motives for purchasing clothes by consumers are very diverse, there is a limit to analyzing the sales of clothes only by weather factors. However, weather changes are becoming more extreme due to climate change. The merchandising plan and effective communication cannot control the weather; nevertheless, the clothing industry must regularly respond to weather changes. This study contributes to informing the importance of weather factors as a management component to clothing professionals and weather scientists and disseminating the awareness of integrated research on the use of weather information as a management tool.

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**Declarations**

**Conflict of Interest** The authors declare that they have no conflict of interest.

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