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Impact of Climate Change Disclosure on Financial Performance: An Analysis of Indian Firms

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Abstract

This paper investigated the relationship between the climate change disclosure and the firms' financial performance in the Indian context. The climate change disclosure scores assigned by the Carbon Disclosure Project (CDP) survey to 44 participating Indian firms during 2011 to 2015 is being used to determine the extent of climate change disclosure. Further, Return on Equity (ROE) and Return on Assets (ROA) are being used to proxy the sample firms' financial performance. After controlling for industry- and firm-specific variables, we observed that the ROE will be higher for companies having higher environmental disclosure scores comparatively the companies having low environmental disclosure scores. Moreover, the results of the regression analysis revealed that the market perceives the voluntary climate change disclosure as a positive corporate initiative, leading to significant positive regression coefficient. However, this study did not find any evidence to supports that the climate change disclosure affects ROA. These findings are crucial for managers and the investors to assess the economic consequences of voluntary environmental disclosures by the firms operating in emerging economies.

1 Introduction

Climate change and global warming are the defining challenge of our age. International and national efforts have been made to mitigate the same. In order to reduce emissions of six greenhouse gases (GHGs) by 5.2 per cent from the 1990 level, the UNFCCC (United Nations Framework Convention on Climate Change) adopted an international environmental treaty in 1997, which is popularly known as Kyoto Protocol. It comes into existence on 16th February 2005. Further, India, the world's fourth-largest GHGs emitters as of 2015, has also announced National Action Plan on climate mitigation with the aim to reduce emission intensity by 20 per cent to 25 per cent by 2020 compared to 2005 levels in line with India's Copenhagen pledge, which elucidated eight bottom 'national missions' running through 2017. Moreover, in the climate change regime the firms are also facing internal, economic, regulatory, financial market and social pressure from different stakeholders to report on their climate change actions (Luo et al., 2013). The literature on the effect of climate change disclosure on the firms financial performance have become a matter of interest for the governments of different countries,

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policymakers, society, investors, business community and academicians as well. Keeping in view all these, the Carbon Disclosure Project (CDP) in 2000 has been launched. Its resultant firms are encouragingly responding to measure, report and manage their climate change actions and integrate this into their assessment of the financial performance as well as long-term prospects of their business. As environmental performance and disclosure influence a firm's financial performance in the capital market (Freedman and Jaggi, 1982; Dye, 1985; Ullmann, 1985; Dowell et al., 2000; King and Lenox, 2001; Konar and Cohen, 2001; Al-Tuwaijri et al., 2004; Luo et al., 2012; Saka and Oshika, 2014; Flammer, 2015; Qiu et al., 2016), resultant, firms with better climate change disclosure have a less environmental risk exposure, a good reputation, better financial performance in the market and customer loyalty (Jacobs et al., 2010).

A few of important studies have attempted to provide a better understanding of firms' climate change management practices and its impact on a firm's financial performance (Palmer et al., 1995; Blacconiere and Northcut, 1997; Bae and Sami, 2005; Stern, 2007; Kim and Lyon, 2011; Fisher-Vanden and Thorburn, 2011; Hsu and Wang, 2012; Griffin et al., 2012; Saka and Oshika, 2014; Matsumura et al., 2014) in developed countries. However, very few researchers have studied the relationship between the environmental disclosure and firms' performance in developing countries, particularly those in Asian countries (Lee et al., 2015). So, motivated with this research gap, the present analysis contributes to the literature in several ways. The study is the first to examine the relationship between climate change disclosure and financial performance in the Indian context. Second, lots of work have been done to examine the relationship between environmental disclosure and the financial performance. However, previous studies have produced mixed results for the effects of climate change disclosure on corporate financial performance. Some studies have found a positive correlation between the two variables (*i.e.*: Hai et al., 1998; Stanwick and Stanwick, 2000; Gozali et al., 2002; Al-Tuwaijri et al., 2004). Cohen et al. (1995) found a positive relationship between environmental disclosure and corporate financial performance. The study reported that the firms which can reduce social and environmental problems such as natural pollution may able to increase and improve their effective production, reputation and competitive advantages. Similarly, Nakao et al. (2007) in their study also reported that environmental performance can positively influence the corporate financial performance. On the other hand, some researchers found no correlation between environmental disclosure and financial performance (Haslinda et al., 2002; Connelly and Limpaphayom, 2004; Ruslaina et al., 2006; Cormier and Magnan, 2007; Fisher-Vanden and Thorburn, 2011). Haslinda et al., (2002) conducted a study on 40 Malaysian companies listed on KLSE. The study revealed that the relationship between reporting and performance is still inconclusive since only 2 out the 19 items of environmental information examined showed a positive correlation with the profitability of the reporting companies. Similarly, Zauwiyah et al., (2003) reported that the decision to disclose environmental information is negatively correlated with companies' financial leverage. More importantly, Kim and Lyon (2011) also found no association between firm value and carbon information disclosure. So, this study provides a further evidence on the relationship between environmental disclosure and financial performance. Third, the majority of previous studies used market-based criteria of a firm's financial performance e.g. stock price (Blacconiere and Northcut, 1997; Kim and Lyon, 2011; Hsu and Wang, 2012; Griffin et al., 2012; Lee et al., 2015), a very few studies have taken accounting-based criteria of a firm's performance like ROE and ROA. This research also fills this gap in the literature. Fourth, the study provides managers with meaningful implications in terms of making environmental disclosure decisions in the best interests of a firm's financial performance in the market.

The rest of this paper proceeds as follows: The next section provides a brief review of the related literature on the relationship between the climate change disclosures and the financial performance. The data and methodology section describes the research method and variables which are being used in this study. We then present the results of the empirical analysis. Finally, we discussed the implications of the study and a few concluding remarks.

2 Literature review

Existing literature exhibits a positive relationship between the climate change disclosures and a firm's financial performance (*e.g.*: Palmer et al., 1995; Blacconiere and Northcut, 1997; Bae and Sami, 2005; Stern, 2007; Beatty and Shimshack, 2010; Fisher-Vanden and Thorburn, 2011; Hsu and Wang, 2012). Hai et al. (1998) conducted a study with the help of a sample of publicly listed companies in Singapore in order to know the relationship between the environmental disclosure and financial performance. This study reported that the firms which produce environmental disclosure have better financial performance than those that do not. Subsequently, King and Lenox (2001) investigated the relationship between corporate environmental and financial performance. An analysis of longitudinal information and factual techniques found that the firms in cleaner ventures have a higher Tobin's q, however, the study can't preclude conceivable perplexing impacts from fixed firm traits.

Murphy (2002), in his review demonstrated that positive environmental performance, in terms of less carbon emission into the atmosphere and their proper disclosure in books of accounts, improve company's financial performance, in terms of profits, revenue and market value and negative environmental performance have their negative impact, in terms of decreased profits and market value. On the other hand, low-carbon technologies investment, proper emission disclosure and compliance with environmental regulations, produces a favourable return on equity (ROE) and return on assets (ROA) and have a more positive return on their stock. Similarly, Gozali et al. (2002) found that companies with positive environmental disclosures performed significantly better in the market than the companies that disclosed negative environmental information. In the same line, Al-Tuwaijri et al. (2004) also reported that good environmental performance is significantly associated with good economic performance. In addition, Clarkson et al. (2008) revealed in their review study that good environmental performing firms enjoy the benefits to over compliance ("green goodwill", cost advantages due to process innovation, and raising rivals' costs) while poor environmental performing firms do not enjoy these benefits but instead face obligations to incur future abatement expenditures with no incremental return to shareholders as emission standards get.

Salama (2005) confirmed that there is a positive connection amongst corporate environmental performance and a firm's financial performance. Moreover, the study further explored that this positive relationship is more grounded when median regression is used. Similarly, Murray et al. (2006) revealed a positive relation between the level of environmental/social disclosure and the consistency of financial returns. Most importantly, Peloza (2009) depicted that there is a little, however positive connection between corporate social performance and an organisation's financial performance. Later, Clarkson et al. (2011) in their research also showed that firms with superior environmental performance have a favourable financial performance in the market. Whereas, a few studies revealed no relationship between climate change disclosures and a firm's financial performance. For instance, Trebucq and Henri (2002) found no association between corporate social performance and financial performance. In the context of emerging economies, Verma and Singh (2016) also reported no correlation between a firm's profitability and corporate social disclosure (CSD).

Moreover, Albertini (2013) in his review of 52 studies over a 35-year time frame affirms a positive connection between environmental performance and financial performance. Griffin and Sun (2013) also documents that shareholders respond positively to a firm's voluntary green disclosure. In the same vein, Hsu and Wang (2013) examined a sample of firms with news cover again Wall Street Journal (WSJ) during the period 1989-2008. Using event study the results show that firms with more negative words on climate change have significantly positive wealth effects. This study finds that market reaction is less positive in environmentally sensitive industries and in firms with poor environmental performance, though the effect for poor performance is insignificant.

More recently, Lee et al. (2015) reported that the market is likely to respond negatively to firms' carbon information disclosure, implying that investors tend to perceive carbon disclosure as bad news and thus are concerned about potential costs facing firms for addressing climate change. Moreover, a firm can mitigate negative market reaction from its carbon disclosure by releasing its carbon news periodically through the media in advance of its carbon disclosure. The above discussions indicate a positive association between corporate

climate change disclosure and firms financial performance. Taking these discussions together leads this research to the following hypothesis:

H1: Corporate climate change disclosures are positively related to a firm's ROE.

H2: Corporate climate change disclosures are positively related to a firm's ROA.

3 The carbon disclosure project (CDP)

As stated in the begging, firms increasingly are pressurised to report the impact of their corporate actions on climate change. One major initiative is the Carbon Disclosure Project (CDP), the world's largest non-profit organisation which covers 35 institutions with US$4 trillion assets and wanted to see firms reporting reliable, comprehensive information about climate change risks and opportunities (CDP India, 2015). Every year the CDP has sent leading global corporations a questionnaire on the risks and opportunities from climate change, greenhouse gas emissions, emission reduction plans, targets, and strategies, emission intensity, and corporate governance. By publishing the responses with assigned scores on the basis of disclosed environmental aspects associated with a firm, the CDP is working to facilitate active communication between companies and investors. We utilised extent of climate change disclosure on the CDP as a proxy for climate change disclosure by the Indian firms. It is a voluntary self-reporting project initiated to allow for companies to address the issue of climate change and investors to address the risks involved with their investments. The CDP uses measurement and disclosure to advance the managing of environmental threats and through leveraging investors, customers and authorities, it has been able to give incentives to organisations across the largest global economies to report and measure their environmental data. Moreover, the CDP also helps firms to handle the potential risk of information asymmetric due to lack of environmental reporting standards. Otherwise, lack of publicly available information for all investors causes expectations of a higher rate of return on their investment. Consequently, this can negatively influence the earnings of a firm (Easley and O'Hara, 2004).

4 Data and methodology

4.1 Research objective

The main aim of the study is to assess the impact of voluntary climate change disclosure on the firms financial performance. The ROE and ROA are the two financial performance parameters on which the effect of different variables is being assessed.

4.2 Data source and sample selection

We extracted the data needed to measure ROE, ROA and other control variables like size, beta, R&D and leverage of each sample firm from the Prowess Centre for Monitoring Indian Economy (CMIE) Database. Furthermore, climate change disclosure scores were obtained from the Carbon Disclosure Project (CDP) which is the most preferred platform for climate change disclosure by firms throughout the world and are being used in numerous of studies related to voluntary climate change disclosure (*e.g.*: Reid and Toffel, 2009; Matisoff et al., 2012; Li et al., 2014; Saka and Oshika, 2014; Doda et al., 2015). The CDP India reports can easily get from the website of the CDP (https://www.cdp.net/en).

The initial sample population chosen for this study included all firms which disclose their climate change data on the CDP. We excluded nine firms from financial sectors because the regulatory structure or business activities of financial sector firms differ from other industry sectors firms like manufacturing, materials, utilities and industrial firms and they have different reporting procedures, consequently, these companies are not quite comparable (Hossain et al., 1995). Moreover, three firms were not available on Prowess Centre for Monitoring Indian Economy (CMIE) Database. Finally, a sample of 44 firms was formulated (Table 1) and data was selected

Table 1 List of companies under study.

Tata Consultancy Services	Tech Mahindra	Hindustan Petroleum Corporation
Wipro	Dr Reddys Laboratories	JSW Steel
ACC Cements	Ultratech Cement	Bharat Forge
Tata Chemicals	Indian Hotels Co.	Titan Industries
Tata Global Beverages	HCL Technologies	Bharat Petroleum Corporation
Sesa Goa	Ambuja Cements	ONGC
GVK Power & Infrastructure	Tata Communications	ABB
Tata Power Co	GAIL	IL & FS Transportation Networks
ITC	Indian Oil Corporation	Suzlon Energy
Mahindra & Mahindra	Tata Motors	Mahindra Satyam
Larsen & Toubro	Hindustan Zinc	Mindtree Ltd
Tata Steel	Godrej Consumer Products	Asian Paints
Essar Oil	Godrej Industries	NMDC
Infosys Limited	Cairn India	KSK Energy Ventures Limited
Shree Cement	Piramal Enterprises	

Source: Carbon Disclosure Project (CDP)

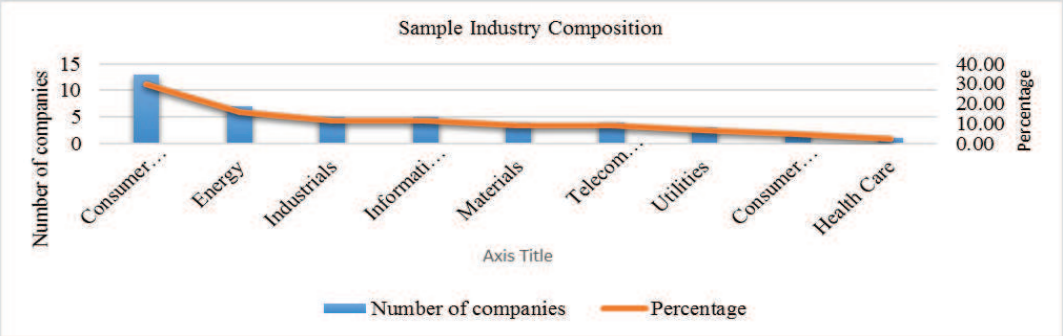

Fig. 1 The sample industry composition.

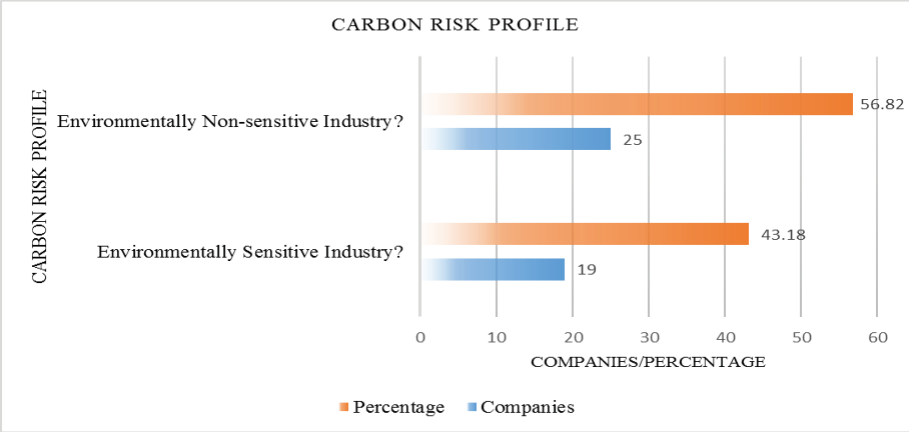

Fig. 2 Carbon risk profile of firms.

Table 2 Sample industry composition and carbon risk profile.

Industrial Sector	Is Environmentally sensitive industry?
Consumer Discretionary	No
Energy	Yes
Industrials	Yes
Information Technology	No
Materials	Yes
Telecommunication	No
Utilities	Yes
Consumer Staples	No
Health Care	No

Source: Reid and Toffel, 2009; Hrasky, 2011 and Chapple et al., 2013

for the years 2011-2015.

The activity sectors covered under this study (as shown in Figure 1) were Consumer Discretionary (13 firms covered the highest proportion 29.55 percent of total sample), Energy (7), Industrials (5), Information Technology (5), Materials (4), Telecommunication (4), Utilities (3), Consumer Staples (2) and Health Care (1 firm covered the lowest proportion only 2.27 percent of total sample). Out of 44 sample firms, 19 firms (43.18 percent) belongs to environment sensitive industries and 25 firms (56.82 percent) belongs to environment non-sensitive industries (Figure 2).

4.3 Financial Performance Measures

4.3.1 Return on equity (ROE)

Consistent with the prior studies (Hart and Ahuja, 1996; Russo and Fouts, 1997; Haniffa and Cooke, 2005; Shen and Chang, 2009) this research is also used Return on Equity (ROE) as a proxy for firms' financial performance. The ROE is an accounting-based criterion of financial performance which measures the rate of return that the owners of common stock of a company receive on their shareholdings. Return on equity signifies how good the company is in generating returns on the investment it received from its shareholders. The formula for ROE is

$$\text{Return on Equity} = \text{Net Income/Shareholder's Equity}. \quad (1)$$

Note: Net income is for the full fiscal year (before dividends paid to common stockholders but after dividends to preferred stock) and Shareholder's equity does not include preferred shares.

4.3.2 Return on assets (ROA)

Return on assets (ROA) is an indicator of how profitable a company is relative to its total assets. The ROA gives an idea as to how efficient management is at using its assets to generate earnings. It is calculated by dividing a company's annual earnings by its total assets and shown as a percentage. Consistent with the prior studies (Hart and Ahuja, 1996; Russo and Fouts, 1997; Shen and Chang, 2009) we have calculated ROA as follows:

$$\text{Return on assets} = \text{Profit after tax (PAT)/ Total Assets}. \quad (2)$$

Note: Total assets are a sum total of Net Block, Work in Progress and Total Current Assets.

4.4 Methodology and variables of the study

This section describes the econometric and the statistical model used to test the hypotheses. In order to examine the links between voluntary climate change disclosure and a firm's financial performance, two econometric

Table 3 Descriptive statistics of the sample firms.

Variable	Observation	Minimum	Maximum	Median	Mean	Standard Deviation
ROE	220	-0.0616	0.4953	0.1448	0.1604	0.1260
ROA	216	-0.5475	0.8705	0.1195	0.1410	0.1656
CCD Score	143	32.00	100	77	75.16	18.54
SIZE	217	1448.13	498890.7	26517.88	53855.01	74895.15
BETA	219	0.1507	2.1791	0.8454	0.8722	0.3738
R&D	177	0	1305.39	4.55	46.09	155.46
Industry	220	0	1	1	0.5909	0.4927

models are being developed. The general form of the econometric models we used to test our hypotheses are as follows:

$$\text{ROE} = \alpha_0\text{INTERCEPT} + \alpha_1\text{CCD} + \alpha_2\text{SIZE} + \alpha_3\text{BETA} + \alpha_4\text{R\&D} + \alpha_5\text{INDUSTRY} + \varepsilon_t, \quad (3)$$

$$\text{ROA} = \beta_0\text{INTERCEPT} + \beta_1\text{CCD} + \beta_2\text{SIZE} + \beta_3\text{BETA} + \beta_4\text{R\&D} + \beta_5\text{INDUSTRY} + \varepsilon_t. \quad (4)$$

The present study used two explanatory variables such as ROE and ROA as a proxy for firms' financial performance and five control variables like climate change disclosure, size, beta, R&D and leverage were also used. Where INTERCEPT is the intercept. CCD is the corporate climate change disclosures. The corporate climate change disclosure is a measure of the extent of climate change information disclosed in the CDP India reports. We used the climate change disclose scores assigned by the CDP to the sample firms based on the disclosure on different parameters like GHG emissions data, energy conservation, reduction targets etc.

Moreover, consistent with existing literature (*e.g.*: Waddock and Graves, 1997; Hai et al., 1998; McWilliams and Siegel, 2000; Al-Tuwaijri et al., 2004; Salama, 2005), this study also control for firm size; systematic risk; R&D intensity and industry effects. Size is the natural logarithm of total assets which is used to control firm size (Hackston and Milne, 1996). Larger firms tend to have better financial performance than smaller firms. The coefficient of size (α_2) is expected to be positive. Beta was amongst one of the important control variables which measure the systematic risk associated with the industry. This paper predicts coefficient of Beta is positively correlated with ROE and ROA. The R&D is the investment on research and development. INDUSTRY is an industry sector in which sample a firm is operating. Consistent with prior studies (Reid and Toffel, 2009; Hrasky, 2011; Chapple et al., 2013), this study also operationalized IND as a dichotomous variable; taking a score of one if the firm belongs to an environment sensitive industry; and zero, otherwise (Table 2). It is used to control industry effect on the CDP disclosure.

5 Results and analysis

5.1 Descriptive statistics

Descriptive statistics of the sample firms are reported in the Table 3. The financial performances in this study are measured by using ROE and ROA, which are the dependent variables of this study. The mean of ROE is 16.04 per cent which indicates that sample firms are profitable and having a good return on their investment whereas the standard deviation of ROE is 0.1260. The maximum and minimum value of ROE are 49.53 per cent and -0.06.16 per cent which portrays that some sample firms having a quite high return on their investment and some are not able to generate an adequate return on their investment. Furthermore, the second dependent variable used in this study to measure the financial performance is ROA which the mean value of this variable is 14.10 per cent. The maximum and minimum value of ROA are 87.05 per cent and -0.54.75 per cent which is significantly different from each other. These statistics indicate that sample firms consisted some firms with

Table 4 Correlation matrix for a sample of 44 Indian firms over the period 2011C2015.

Variable	CCD Score	SIZE	BETA	R&D	Industry	ROE	ROA
CCD Score	1	0.2686*	-0.0451	-0.1536***	-0.1836**	0.1519***	0.1310
SIZE		1	-0.1889**	0.0029	-0.4102*	0.5640*	0.3661*
BETA			1	0.1991**	0.2810*	-0.3984*	-0.2733*
R&D				1	-0.2204*	-0.0530	-0.0130
Industry					1	-0.4637*	-0.3079*
ROE						1	0.6542*
ROA							1

The significance levels are given by: * = $p < 0.01$, ** = $p < 0.05$, *** = $p < 0.10$

very good financial performance in the market and some of the having a negative return on their assets. The standard deviation for this variable is 16.56 whereas the medium value is 11.95.

The mean value for climate change disclosure (CCD) which is one of the important independent variables of this study is 75.16 which indicates that voluntary climate change disclosure on the CDP during the sample period is getting an overwhelming response from the sample firm. The minimum value of CCD is 32 which shows that few companies disclosed low environmental information on the CDP. Besides, the maximum value is 100 which shows that some sample companies disclosed on all the parameters asked by the CDP. The firms voluntarily disclose more on environmental aspects in order to legitimise their operations (Gray et al., 1995; Deegan and Rankin, 1996; Brown and Deegan, 1998; Deegan, 2002; Campbell, 2003; Chu et al., 2012). The descriptive statistics also provided for standard deviation value of CCD is 18.54 which denote the low dispersion in observations. The median and mean of the beta portrayed in Table 3 are 0.8454 and 0.8722, respectively, which are very high and depict that the sample firms used in the study bear high operating risks. The mean and median values of R&D are 46.09 and 4.55, respectively. In brief, descriptive statistics for independent variables indicate that the sample firms used in this study are large cap, profitable and risky.

5.2 Correlation among variables

A prior condition to apply regression analysis is to test the multicollinearity among independent variables. The correlation matrix amongst variable of the study is presented in Table 4. Climate change disclosure is positively and significantly correlated to ROE at 10 percent level which indicates that firms with better environmental disclosure quality have positive financial performance in the market. Size is positively and significantly correlated with ROE and ROA of sample firms which show that larger firms have better financial performance than smaller firms. Further, Climate change disclosure is negatively and positively correlated with industry which depicts the environmental friendly firms disclose more on the CDP than firms operating in high environmental sensitive industries. Moreover, beta is also negatively and significantly correlated with ROE and ROA of sample firms which indicate that financial risk associated with a firm can influence its financial performance in the market. A severe multicollinearity may produce misleading coefficient. Researchers throughout the world suggested different measure handle the problem of multicollinearity. Some important studies (*e.g.*: Hair et al., 2006) suggested that correlation coefficients below 0.9 may not cause serious multicollinearity problem, while Kennedy (1985) argued the value below 0.8 shows no severe multicollinearity. The correlation matrix (Table 4) portrayed that the correlated coefficient values are below this value, so there is no problem of multicollinearity amongst the variables under study.

5.3 Impact of climate change disclosure on ROE

We used multiple regression analysis to examine the impact of climate change disclosure on firms' financial performance. Moreover, both fixed and random effect models were employed and the Hausman test is used to

Table 5 Regression analysis of the estimated impact of climate change disclosure on the return on equity (ROE).

	Model I	Model II
	Cross-Section Fixed Effect Coefficient (*p*-value)	Cross-Section Random Effect Coefficient (*p*-value)
INTERCEPT	-0.3087 (0.0015) *	-0.0068 (0.9546)
CCD	0.0013 (0.0223) **	0.0006 (0.0961) ***
SIZE	0.1082 (0.0000) *	0.0746 (0.0049) *
BETA	-0.0828 (0.0012) *	-0.0867 (0.0003) *
R&D	-7.0905 (0.1452)	4.6205 (0.2944)
INDUSTRY	-0.0673 (0.0005) *	-0.0605 (0.0322) **
Adjusted R-Squared	0.496487	0.193278
F-statistic	14.03771	6.702092
Prob (*F*-statistic)	0.000000	0.000016

The significance levels are given by: * = $p < 0.01$, ** = $p < 0.05$, *** = $p < 0.10$.

choose between the two models having the null hypothesis of using random effect model results. The Table 5 reports the results of the impact of climate change disclosure on ROE using regression analysis.

The results of Model (I) and (II) in the Table 5 portrayed that climate change disclosure is positively and significantly related with ROE at the five per cent and 10 per cent levels (p-value < 0.05 and $p < 0.10$). These findings confirmed our H1 that firms' climate change disclosure affects ROE in the market. These outcomes are consistent with the prior environmental disclosure studies (*i.e.*: Hai et al., 1998; Stanwick and Stanwick, 2000; Gozali et al., 2002; Al-Tuwaijri et al., 2004).

Empirical results for control variables that are related to the firms' financial performance are also reported in the Table 5. The result of Models (I) and (II) shows that the coefficient for the firms' size is positively and statistically significantly associated with ROE at the one per cent levels (p-value < 0.01). In other words, the climate change disclosure quality produces a favourable ROE and ROA for sample firms (Murphy, 2002). The coefficient of size in Model (I) and (II) were found to be positively and significantly related to ROE at the one per cent levels (p-value).

5.4 Impact of climate change disclosure on ROA

This section provides the detailed results and the analysis of the impact of climate change disclosure on ROA. Models (I) and (II) of the Table 6 depicts the results for H2. The outcomes of Model (I) and (II) in the Table 6 shows that there is no significant relationship between climate change disclosure and ROA. Contrary to the existing literature (*i.e.*: Hai et al., 1998; Stanwick and Stanwick, 2000; Gozali et al., 2002; Al-Tuwaijri et al., 2004), findings of the study revealed that the voluntary climate change disclosure is an immaterial decision. Moreover, results of regression model rejected our null hypothesis that corporate climate change disclosure is positively related to firms ROA.

In addition, outcomes for independent variables that are related with the firms' ROA are also reported in the Table 6. The result of Model (I) and (II) shows that the coefficient for the firms' size is positively and statistically significantly associated with ROA at the one and five per cent levels ($p-$value < 0.01 and p-value < 0.05), respectively. These results indicate that larger firms have better ROA than smaller firms. Furthermore, the coefficient for beta is negatively and significantly related to ROA in Model (I) and (II) at the 10 per cent levels (p-value<0.10), which is consistent with the fact that the firms with the high financial leverage have lower ROA. Moreover, industry is also negatively and statistically significantly related to ROA in the Models I at 10 percent level (p-value<0.10). These results are consistent with the argument that firms operating in high environmental sensitive industries have lower ROA than firms operating in the low environmental sensitive industry sector. However, this paper does not find any evidence to support that sample firms' R&D affects ROA of the sample firms.

Table 6 Regression Analysis of the estimated impact of climate change disclosure on the Return on Assets (ROA).

	Model I	Model II
	Cross-Section Fixed Effect Coefficient (*p*-value)	Cross-Section Random Effect Coefficient (*p*-value)
INTERCEPT	-0.2351 (0.1585)	-0.1489 (0.4071)
CCD	0.0012 (0.2336)	-0.0002 (0.7927)
SIZE	0.0902 (0.0054) *	0.0851 (0.0247) **
BETA	-0.0819 (0.0629) ***	-0.0807 (0.0707) ***
R&D	-3.1305 (0.7108)	1.5905 (0.8569)
INDUSTRY	-0.0579 (0.0820) ***	-0.0457 (0.2303)
Adjusted R-Squared	0.159059	0.084971
F-statistic	3.500897	3.210094
Prob (*F*-statistic)	0.000768	0.009498

The significance levels are given by: * = $p < 0.01$, ** = $p < 0.05$, *** = $p < 0.10$.

6 Conclusion

This paper investigates the impact of the climate change disclosure on firms financial performance. The question raised was whether ROE and ROA will be affected by the voluntary environmental disclosure under the CDP. The present study has revealed mixed results for the effects of climate change disclosure on the firms' financial performance. Our results indicate that there is a significant positive relationship between the corporate climate change disclosure and Return on Equity (ROE). The study further explores that ROE will be higher for companies having higher environmental disclosure scores comparatively the companies having low environmental disclosure scores. However, no significant relationship is detected between the corporate climate change disclosures and Return on Assets (ROA).

Climate change has become a debating issue at national and international level. The corporate houses also recognised the phenomenon, resultant, they voluntarily started to disclose more on the environmental aspects in order to legitimise their operations (Gray et al., 1995; Deegan and Rankin, 1996; Brown and Deegan, 1998; Deegan, 2002; Campbell, 2003; Chu et al., 2012) and to avoid the potential risk of information asymmetric for all investors (Easley and O'Hara, 2004). Along with these lines, financial implications of the voluntary environmental disclosure are getting more public exposure and important in the value creation processes of the firms, but reporting standards are almost silent in this regard. Consequently, stakeholders need to rely on voluntary climate change disclosure on the CDP in order to better assess the environmental implications of the firms' operations (Bauer and Hann, 2010; Orens et al., 2010; Chaklader and Gulati, 2015). So, it is the responsibility of regulators to facilitate the provision of such information disclosure by the firms without comprising the need of various stakeholders *e.g*. investors.

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Estimates of the Effectiveness for Urban Energy Conservation and Carbon Abatement Policies: The Case of Beijing City, China

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Abstract

Cities play an important role in tackling climate change, as they consume close to 2/3 of the world's energy and account for more than 70% of global greenhouse gas emissions. To assess the effectiveness of urban energy conservation and carbon mitigation measures, a detailed Long Range Energy Alternatives Planning (LEAP) model is developed and applied to simulate a series of emission reduction measures. The developed LEAP model is also aimed at analyzing how these emission reduction measures change energy consumption and carbon emission from 2016 to 2050. Fifty scenarios were defined to describe the future energy strategies in relation to the development of Beijing city, including a 'Business as Usual' scenario, 42 sub-scenarios, 4 sectoral compound scenarios and 3 system compound emission reduction scenarios. The 'Business as Usual' scenario assumes that the government will do nothing to influence the long-term trends of urban energy demand. The 42 sub-scenarios reflect the effectiveness of singular measure including clean energy substitution, terminal technological innovation, industrial structural adjustment in three energy demand sector as well as external input of power scenario in transformation sector. Each singular measure has three A, B, C three levels, which represent different intensity of the measure. Sectoral compound scenarios show the integrated effectiveness of B-level measures which reflects the strength of the existing policy in each sector. The final effectiveness of all energy conservation and carbon mitigation measures of assorted level are presented in 3 system compound emission reduction scenarios. A further analysis of decoupling relationship between energy consumption and economy under system compound scenarios is discussed.

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Results show that, in Beijing under current policy, carbon emission will rebound in 2035 and continue to grow until 2050. If the intensity of each measure are enhanced, the rebound can be avoided. Doing so, Beijing energy consumption and economic growth might become strongly decoupled by 2040. Terminal technological innovation of service industry in building sector, appropriately monitored along its development, is the most effective measure, while the transportation sector has the largest carbon emissions abatement potential. Finally, the currently planned externally transferred green power measure also shows a clear emission reduction potential.

1 Introduction

Curbing global warming and cutting carbon emissions have become the consensus of all Countries in the 21st century (Solomon et al., 2009; Moss et al., 2010). Carbon emissions from energy use in cities are the most important sources of greenhouse gases. With high concentrations of both population and economic activities, cities have become the hot spots for energy demand and carbon emissions (Wang et al., 2017; Basosi et al., 2017; Rosenzweig et al., 2018). In China 56% of the population live in urban areas in 2015. Moreover, 150 cities accounted for 70% of China's total CO_2 emissions in 2010 (Liu, 2016). Under rapid urbanization, Chinese residents are continually migrating from rural to urban areas. In the next two decades urban population could reach 1 billion (Bai et al., 2014). This puts tremendous pressure on energy demand and CO_2 emissions. Thus, Chinese cities will play a greater role in the future in supporting their Country to achieve its international and national climate goals.

Reducing carbon emissions from regulations, policies, and plans is an important part of current carbon emissions reductions in China. Scientific evaluation and analysis to assess the emission reduction potential of various measures is the basis for improving the quality of policy making (Lei et al., 2017; Liu, 2016; Liu et al., 2013; Wang et al., 2017; Zhang et al., 2017). A better understanding of the effectiveness of city-level measures will help to devise a much needed integrated management framework, as well as to design and implement policies for addressing urban development, energy, and climate change concerns collectively (Su et al., 2012; Chen et al., 2017).

A large amount of existing research on urban CO_2 emissions modeling and projection have been done (Wang and Liu, 2017; Miao, 2017; Wang et al., 2017; Wang and Li, 2017; Singh and Kennedy, 2015). Previous CO_2 modeling approaches included regression models, IO model, SD model, MARKAL model, and LEAP model. Among these approaches, Long-Range Energy Alternatives Planning System (LEAP) model is the most popular way to evaluate the future energy consumption and CO_2 emissions due to its powerful accounting ability, which allows for an analysis rich in technological specifications and end-use details and allows the user flexibility in setting modeling parameters and data structure (Lin et al., 2010; Yu et al., 2015; Lin et al., 2018).

However, most of these studies are concentrated on one or several sectors, while having a generally larger scale of research. From the perspective of the overall urban scale, relatively few researches on energy conservation and emission reduction potential for all sectors are conducted. Handayani et al. (2017) developed and analyse four scenarios of the Java-Bali power system expansion from the base year 2015 through to 2030 using LEAP. Based on LEAP model, Kachoee et al. (2018) simulate the electricity supply and demand in Iran for the next three decades in business as usual, low-carbon and renewable energy scenarios based on various possible policies. Awopone et al. (2017) used Schwartz's Scenario Methodology and LEAP model to examine the current electrical generation expansion plan of Ghana and compares it with proposed expansion pathways with higher penetration of Renewable Energy Technologies. Yang et al. (2017) employed a LEAP model to simulate six energy sectors-related GHG emissions in a pilot low-carbon Ningbo city, China. Fan et al. (2017) took Beijing's public transport as an example, applying the LEAP model to analyze the energy demand and the main greenhouse gas (GHG) emissions under different scenarios during the period 2016 to 2030. Chang et al. (2017)

conducted a regional power generation system modelling and optimization framework using LEAP, focusing on analysis of capacity additions for different power generation technologies, as well as energy inputs, reduction co-bene?ts and system costs in Shanghai. Besides, the detailed design of the scenarios makes this study different from other studies.

Most of the LEAP-model-based studies only set up compound scenarios and did not set multiple intensities for selection. In this study, there are a large number of scenarios and they are divided into three levels of A, B, C, which can better simulate the effects of policies. This study consists of five steps: (a) collecting information on local urban policies and measurements; (b) designing the corresponding scenarios; (c) constructing and applying the LEAP model to generate and analyze a reliable future trend of energy demands and carbon emissions in the Beijing city area from 2015 to 2050, under fifty scenarios; (d) assessing the effectiveness of various measures aimed at energy savings and carbon emission reductions; and finally (e) discussing implementation of current measures, future reduction measures, and implications for other cities. The results can provide valuable input for Beijing's future energy planning and policy making, and it may provide some general insights on the effectiveness of urban-level energy conservation and carbon reduction for other cities as well.

2 Methodology

2.1 Model structure

This study, based on the Green Resources and Energy Analysis Tool (GREAT) framework of the Berkeley China Energy Research Institute, develops a LEAP-Beijing carbon emission scenario analysis framework, as shown in Fig.1. The framework includes four modules: Key Assumption, Demand, Transformation, and Resources.

The model considers the energy consumption and transformation sector, covering all major primary and secondary energy sources used in Beijing. The analysis spans from 2015 to 2050, considering year 2015 as the base year. The driving factors of the model include economic growth, population growth, industrial restructuring, technological progress, energy efficiency improvement and energy structure adjustment. It includes four end-use sectors: agriculture, industry, building (including energy consumption for construction activities and energy use for buildings), and transportation. According to the characteristics of each sector's energy requirements and the availability of corresponding statistics, its sub-sectors, terminal equipment and fuel types are included in the scenario analysis.

The LEAP model we established lays the energy consumption generated by the service industry and people's daily lives under the same directory of the building sector which is different from other studies. The above two types of activities all belong to the energy consumption of human activity. This setting is convenient to set the parameters for further scenario analyses involving residential and commercial buildings under planning. In addition, the energy transformation system in the model consists of two parts: power generation and heating, including only its conversion process, and the distribution of electricity and heat transport is included in the production and supply of electric power, gas and water part of the industry.

2.2 Calculation of energy consumption

For the energy sector, LEAP can model the energy consumption, conversion and supply under given scenarios which are represented by specific economic and technological development.

The total energy consumption is the aggregation of two parts: final energy demand and energy consumption of conversion process, as shown in Equation (1):

$$EC = ED + ET, \tag{1}$$

where EC is the total energy consumption, ED and ET are energy demand for end-use sectors and energy consumption of energy conversion processes, respectively. The secondary energy consumed for final energy demand is converted from primary energy. Thus, to avoid double counting, only the latter one is accounted.

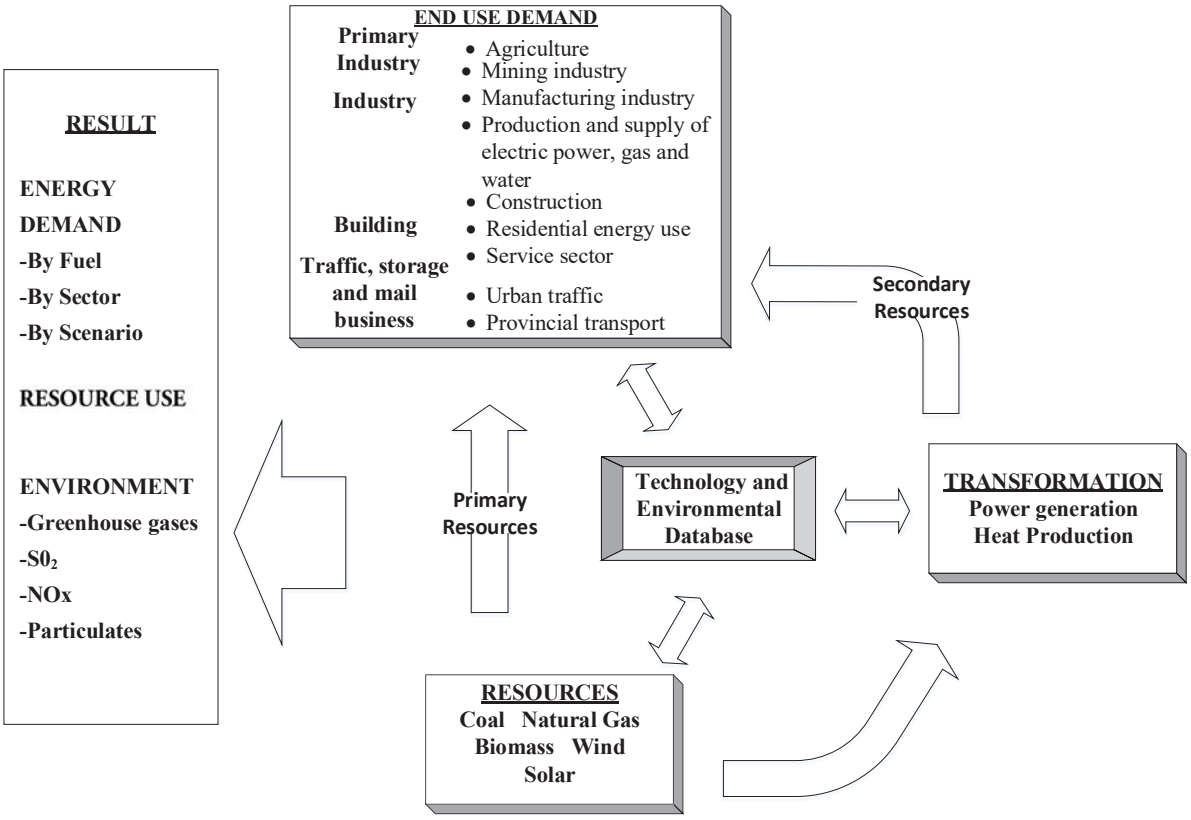

Fig. 1 The overall structure of LEAP-Beijing.

The final energy demand module (*ED*) is generally disaggregated in a hierarchical tree of sectors and subsectors depending on data requirements, in which energy demand of these sectors are calculated from the products of activity level and energy intensity:

$$ED = \sum_i \sum_j \sum_k AL_{i;j;k} \times EI_{i;j;k}, \tag{2}$$

where *AL* is the activity level, *EI* is the energy intensity, *i* is sectors, *j* is the subsectors, and *k* is the type of fuel. Activity level refers to the measure of certain energy-related activities, which might include social and economic indexes such as population, GDP, number of energy users, area of land use, and others.

The energy conversion module (ET) describes how primary energy is converted into secondary energy form. The required primary energy for conversion is the function of electricity or heat generated and the conversion efficiency, of which the former is the products of installed capacity and maximum availability of the generator under the constraint of dispatch rules, and latter is the rate of the production of secondary energy and energy consumption for conversion:

$$ET = \sum_l \sum_m \sum_n \frac{ETP_{1;m;n}}{\theta_{l;m;n}}, \tag{3}$$

where *ETP* is the production of secondary energy in conversion process, θ is the conversion efficiency, *l* is the specific power plant, *m* and *n* are the type of energy consumed and produced in the conversion process respectively.

2.3 Calculation of carbon emissions

Paralleling the two components of energy consumption (i.e.: energy demand and energy transformation), also carbon emissions have two parts: emissions from energy demand and emissions from transformation.

Carbon emissions from energy demand can be calculated as follows:

$$ED \quad Emission = \sum_i \sum_j \sum_k AL_{i;j;k} \times EI_{i;j;k} \times EF_{i;j;k}, \tag{4}$$

where *ED Emission* is the GHG emissions, $EF_{i;j;k}$ is the GHG emission factor from fuel type k through subsector j from sector i, and $EF_{i;j;k}$ is drawn from statistics, the LEAP technical database.

Carbon emissions from energy transformation are calculated as follows:

$$ET \quad Emission = \sum_m \sum_n \sum_t ETP_{m;n;t} \times e_{m;n;t} \times EF_{m;n;t}, \tag{5}$$

where *ET Emission* is the GHG emissions, *ETP* is the energy transformation product, $e_{m;n;t}$ is the emissions factor of producing unit secondary fuel type n from fuel type m through equipment t, and $EF_{m;n;t}$ is drawn from statistics, the LEAP technical database.

3 Case study

3.1 Study area and data source

Beijing is located in the North of China Plain. It is the world's most populous capital city, having a total permanent resident population of 21.705 million in year 2015 within its municipality. The population density was about 1,323 inhabitants per square kilometer. Beijing's gross domestic product (GDP) reached 2.3 trillion yuan in 2015, up 6.8% from 2014. Its GDP per capita was 106,034 yuan, 6.9% higher than 2014. The rapid economic growth and urbanization generated rising energy consumption and carbon emissions in Beijing city. In particular, Beijing total energy consumption in 2015 was 68.5 million tons of coal equivalent, with a total electricity consumption of 95.3 billion kilowatt-hours. In 2015, Beijing's total amount of energy-related carbon emissions were 73.1 million tons of CO_2-equivalents.

Beijing has enacted the comprehensive planning for low-carbon development and energy saving. It is shown in "Beijing Energy Saving and Climate Change Planning in the 13th Five-year Period" that Beijing's total amount of energy consumption should be controlled within 76.51 million tons of coal equivalent by 2020, while energy consumption per unit of GDP should decrease 17% compared with the value in 2015. Since 2015, the "13th Five-Year Plan" series of plans and the "Beijing Overall Planning (2016-2035)" have been promulgated. The strategy of gut the city of all functions unrelated to its status as national capital has provided new impetus and opportunities for energy conservation and emission reduction. Under a clear normalization of the transformation and development of the new normal, Beijing's emission reduction path should change compared to the past. However, new emission reduction paths need to be clarified. This case study aims to use Beijing as an example to analyze the current situation of energy consumption and carbon emissions in this city and to predict the energy consumption and carbon emissions in Beijing over the next 30 years. Afterwards, through scenario analysis, the implementation of mitigation measures was simulated to explore the emission reduction paths and low-carbon development models of cities.

The "energy use" sub-sector data used in this study come from the Beijing Statistical Yearbook (2015). For driver variables (Gross Domestic Product of every sector, population and urbanization rate, etc.). Technical variables (energy efficiency for certain processes or terminals, the promotion rate of different fuels and the proportion of more efficient and low efficiency technology in the total activity level) are determined by the following documents: Environmental Protection and Ecological Construction Planning during "the 13th Five-Year Plan" in Beijing; Beijing Overall Planning (2016-2035); Energy Development Plan during "the 13th Five-Year Plan" in Beijing"; Energy Saving and Climate Change Responding Planning in Beijing during the "13th Five-Year" period; Civilian Building Energy-saving Development Plan in the "13th Five-Year" Period in Beijing; Traffic development and construction plan during the "13th Five-Year" period in Beijing; Beijing's industrial

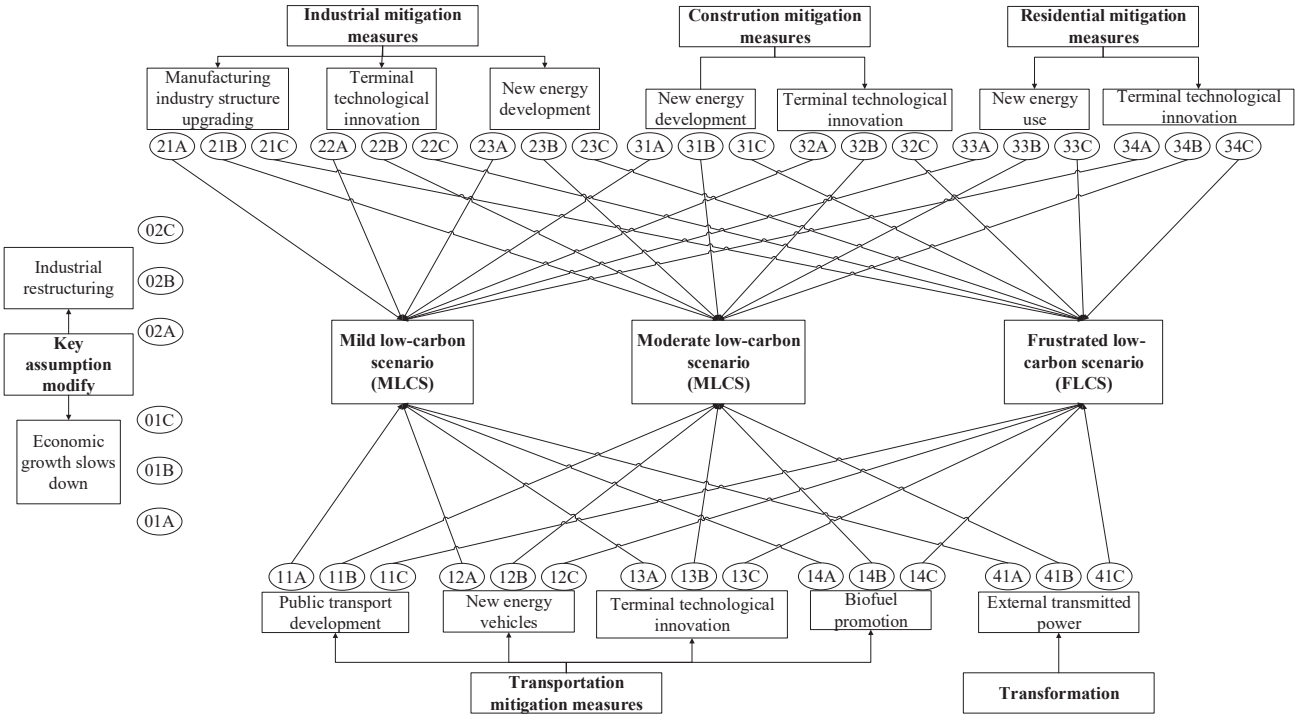

Fig. 2 All scenarios setting in LEAP-Beijing.

transformation and upgrading plan in the "13th Five-Year" period; Major Infrastructure Development Plan during the "13th Five-year Plan" Period in Beijing; etc. The specific parameter settings in each scenario can be found in the Appendix.

The emission factors used in this study come directly from LEAP's Technology and environmental database, which is based on the IPCC National Greenhouse Gas Inventories guidelines.

3.2 Scenario settings

In this study, a business as usual scenario, 42 sub-scenarios, four sectoral compound scenarios and three systems of compound emission reduction scenarios, for a total of 50 scenarios, are built up. There are three levels of A, B and C in the sub-scenarios, of which the measures of level B represent the strength of the policy implemented in the current planning document. The parameter settings are derived from government planning. A-level measures represent lighter-level measures, and C-level measures represent measures that are further strengthened under the existing plans. The upper limit is set with reference to relevant research and other urban development status. Sectoral compound scenarios include industrial emission reduction measures, building emission reduction measures, and traffic-type measures. They are the result of the superposition of Level B measures in the same sector. The four system complex scenarios are a superposition of the same level of measures in 42 sub-contexts. Mild low-carbon scenario includes all A-level scenarios, Moderate low-carbon scenario includes all B-level scenarios, and Frustrated low-carbon scenario considers all C-level scenarios. The correspondence between all scenarios is shown in the figure below.

In the process of scenario analysis, a qualitative analysis of the macroeconomic and social factors, that affect energy demand, and the possible evolutionary trends in the future were developed. We quantified population development, industrial structure and sector structure on the basis of the above analysis. For the set scenario, this paper simulates the adjustment of sector structure, energy consumption structure adjustment and possible technological progress under different scenarios, trying to analyze the approach and the attainable degree of energy development in Beijing. By setting these parameters for each module under different scenarios, the

Table 1 Beijing's economic growth rates in different development stages.

Stage	2016-2020	2021-2025	2026-2030	2031-2035	2036-2040	2041-2045	2046-2050
Growth rate	6.5%	5.5%	4.5%	4.0%	3.5%	3.0%	2.5%

Note. The change in GDP in the sub-scenario of slowing economic growth (01A/01B/01C) is different from the above table. Other scenarios are the same.

Table 2 The change in the structure of three industries in future Beijing.

Year	Primary industry	Industrial industry	Tertiary industry
2015	0.6%	16.0%	75.4%
2025	0.7%	13.6%	80.0%
2030	0.8%	11.3%	82.0%
2035	1.0%	10.1%	83.0%

energy consumption and carbon emission paths of various sectors in Beijing under different emission reduction policies and measures can be analyzed. Key Assumption parameter settings are shown in Tables 1 and 2.

3.2.1 Economic growth

Based on "Beijing 13th Five-year Planning Outline", "Beijing Urban Mater Plan (2016-2035)" and their previous studies, the predictions of national economic growth rate made by some domestic experts and the suggestions from Beijing Municipal Commission of Development and Reform were absorbed to draw the conclusion that Beijing's economic growth would slow down gradually. The economic growth rates set in different development stages are shown in Table 1.

3.2.2 Population

In the light of "Beijing 13th Five-year Planning Outline" and "Beijing Urban Mater Plan (2016-2035)", the growth rate of Beijing's population will witness a slightly dropping trend. At the end of 2015, Beijing's permanent resident population was 21.705 million. Then, the population grew up to around 22 million in 2017 and should reach 23 million in 2020. Afterwards it is foreseen to be stable for a quite long time.

3.2.3 Industrial structure

The change in the structure of three industries, as shown in Table 2, in future Beijing refers to the research findings in Liu (2016) and the historical trend during 2005-2015.

Other parameter settings and their correspondence with the policies are shown in the Appendix Table A1.

4 Results & analysis

4.1 Total energy consumption

Figure 3 shows the changes in energy consumption over time in the Business As Usual scenario and three system compound scenarios.

Total energy consumption growth, except than for the Frustrated low-carbon scenario, which will reach its peak point in 2025, will steadily increase until 2050. With different growth rates in four scenarios, the energy consumption, under the baseline scenario, in 2050 reaches 208.62 Mtce, with an average annual growth rate of 2.97%, which is the highest of all scenarios. Due to a series of energy conservation and emission reduction policy measures, the total energy consumption under the Mild low-carbon scenario, Moderate low-carbon scenario and Frustrated low-carbon scenario will grow at a slower pace. The average growth rates are 1.42%, 0.88%, and 0.30%. As time goes on, the gap between the baseline scenario and other three scenarios, as well as the gap

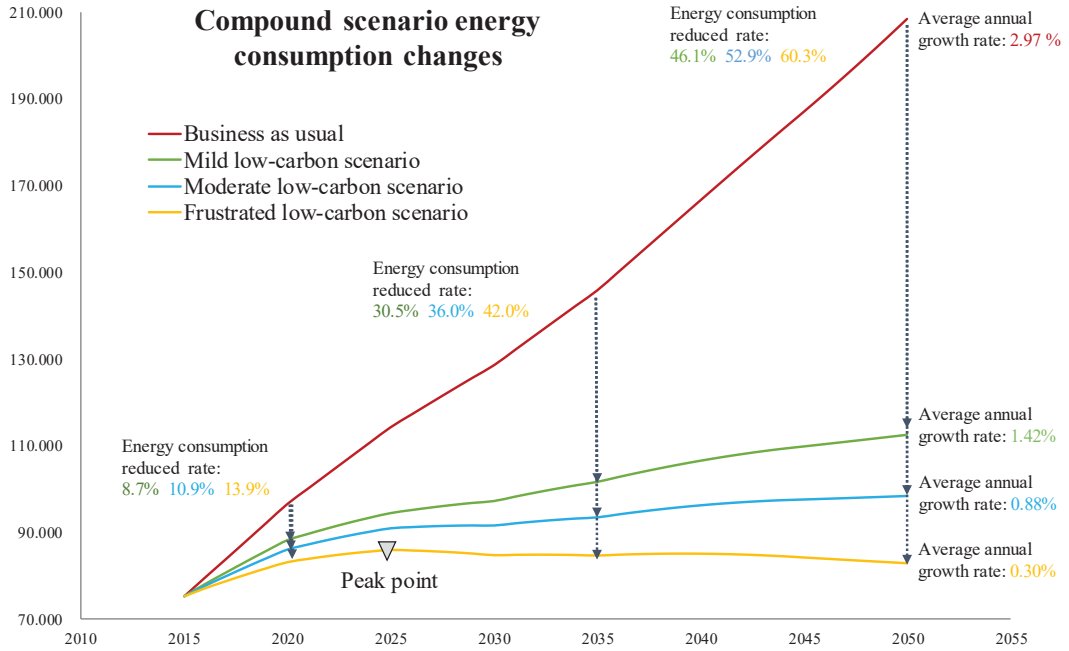

Fig. 3 Compound scenarios energy consumption changes.

among the three complex scenarios, increases in terms of energy consumption. In 2020, the emission reduction ratios of the three composite emission reduction scenarios should reach 8.7%, 10.9%, and 13.9%, respectively. This proportion might increase to 30.5 %, 36.0 % and 42.0 % in 2035. By 2050, the proportion of emission reductions should rise to 46.1%, 52.9%, 60.3%. The results show that current policies or even lighter ones can effectively reduce the city's dependence on energy in the future. However, if Beijing wants to achieve peak point of energy consumption as soon as possible, the intensity of policies should be further adjusted.

4.2 Reduction potential of energy consumption

The overall energy saving potential of various sectors, as well as the dispersion degree of sub-scenarios, can be obtained from Table 3. The table lists the energy consumption of each sub-scenario under the three important time nodes of 2020, 2035, and 2050. The sub-scenarios, that change the key assumption, have a strong degree of differentiation. Among them, measures to slow down the economic growth show better emission reduction effects. According to the current economic growth control policy, the emission reduction ratio in 2020 will be 1.61%, rising to 6.85% and 12.34% in 2035 and 2050 respectively. If the economic growth rate is further slowed down, the emission reduction ratio can almost be twice of the current policy. For the policy of adjusting the industrial structure, its emission reduction effect is less than 3%, indicating that under the circumstance of constant economic development, the adjustment of industrial structure has little effect on energy conservation.

For the compound scenarios of the sectors, the contribution of the construction sector is the largest. Compared with the baseline scenario of the same year, the energy saving ratio in the year 2035 is 20.41%, and it rises to 30.37% in 2050. The highest contribution rate is from Building terminal technology development. This type of policy achieves energy conservation by reducing the intensity of energy consumption in energy use terminal operations. This fact proves that the service industry has become the top emission reduction direction now and even in the future.

The industrial sector follows the construction one. In 2020, the reduction rate should reach 4.60%. However, unlike the building sector, the growth rate of emission reduction is relatively slow in subsequent years. The ratios of energy saving in 2035 and 2050 are 11.69% and 18.03% respectively. In particular, the industrial sector is still one of most relevant sectors for reducing emissions in the future. Finally, it is the traffic sector. In three

Table 3 Sub-scenarios energy consumption changes.

Scenarios	2020	2035	2050	Scenarios	2020	2035	2050
01A	-0.65	-2.82	-5.18	21B	-1.21	-2.04	-3.23
01B	-1.61	-6.85	-12.34	21C	-1.69	-2.45	-3.67
01C	-2.56	-14.43	-22.01	22A	-2.56	-7.95	-13.12
02A	-0.28	-0.29	-0.31	22B	-3.18	-9.54	-15.34
02B	-1.02	-1.21	-1.28	22C	-4.16	-11.94	-18.59
02C	-1.77	-2.13	-2.25	23A	-	-	-
Transportation	-1.32	-3.73	-4.53	23B	-	-	-
11A	-0.40	-0.42	-0.41	23C	-	-	-
11B	-0.31	-0.46	-0.60	Building	-5.18	-20.41	-30.37
11C	-0.50	-0.72	-0.69	31A	-	-	-
12A	-	-	-	31B	-	-	-
12B	-	-	-	31C	-	-	-
12C	-	-	-	32A	-4.06	-16.72	-25.50
13A	-0.39	-1.25	-1.79	32B	-4.85	-19.44	-28.97
13B	-0.76	-2.36	-3.27	32C	-5.62	-21.90	-31.88
13C	-1.13	-3.36	-4.52	33A	-	-	-
14A	-0.36	-1.14	-1.23	33B	-	-	-
14B	-0.40	-1.23	-1.30	33C	-	-	-
14C	-0.44	-1.33	-1.38	34A	-0.23	-0.75	-1.07
Industrial	-4.60	-11.69	-18.03	34B	-0.46	-1.43	-1.97
21A	-0.72	-1.63	-2.80	34C	-0.68	-2.04	-2.73

node years, the energy saving ratio of this sector is below 5%, and the sub-situation energy consumption curve is also relatively concentrated, which proves that there is still greater emission reduction potential in the future.

4.3 The decoupling relationship between energy consumption and economy

In the development process of Beijing, economic growth relied much on energy consumption. In the future, the government hopes to change the mode of economic development, achieving a decoupling of economic development from energy consumption. This goal has also been reflected in the planning. Calculations have been done to check the relationship of economic development assumption and energy consumption result in our model. According to the study of Tapio (2005), the decoupling relationship between energy consumption and economy can be calculated through the value of Tapio index (as shown in Equation (6), the elastic coefficient of economic growth and energy consumption) to determine the relationship between energy consumption and economy.

$$e_{(E,GDP)} = \left(\frac{\Delta E}{E} \Big/ \frac{\Delta GDP}{GDP}\right) \tag{6}$$

where $e_{(E,GDP)}$ is the decoupling level of Beijing's energy consumption and CO_2 emissions. Different $e_{(E,GDP)}$ values indicate different decoupling statuses.

The decoupling statuses can be categorized into three categories, and then further divided into eight sub-categories, as presented in Figure 4. In order not to over interpret slight changes as significant, the $\pm 20\%$ variation of the elasticity values around 1.0 is here still regarded as coupling. Hence, 0.8 and 1.2 are two important numbers for setting the boundary of decoupling statues.

Figure 5 represents the value of Tapio index of energy consumption and GDP under different scenarios in Beijing. The value of the index changes over time from 2015 to 2050. The range of values corresponds

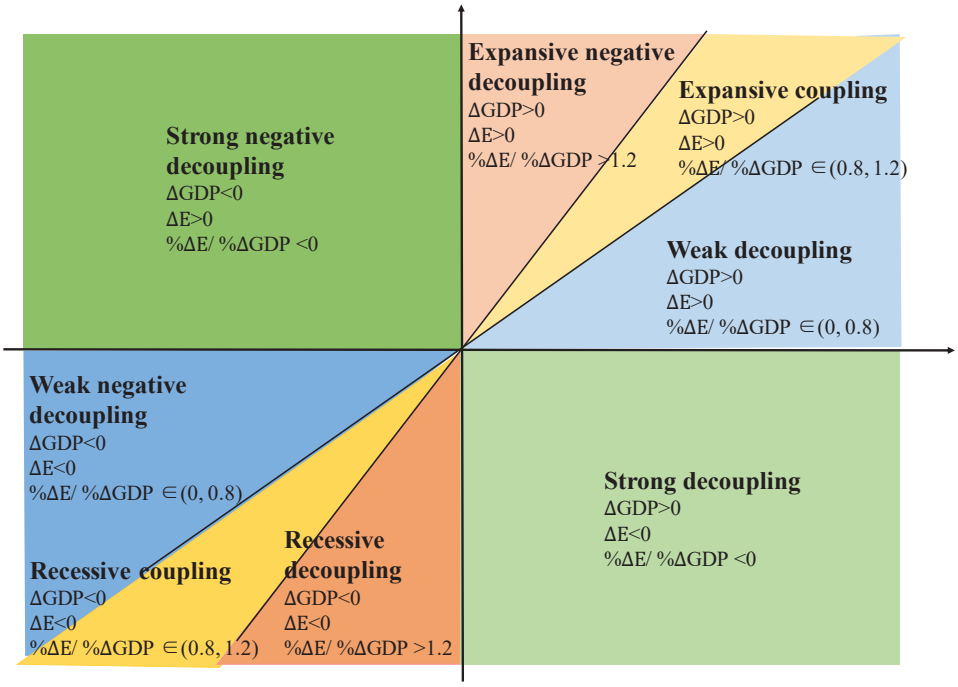

Fig. 4 The degrees of coupling and decoupling of energy consumption (ΔE) from economic growth (ΔGDP).

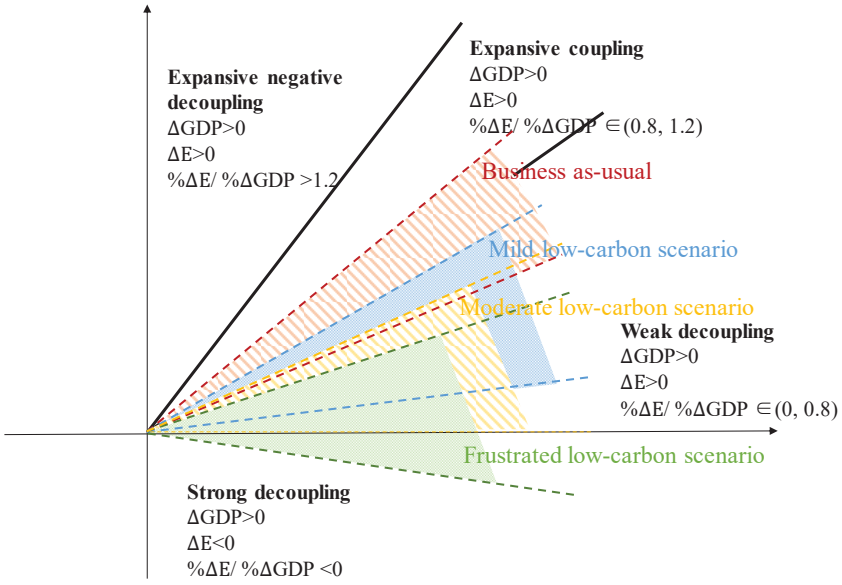

Fig. 5 Decoupling situations under compound scenarios.

to the shade of different colors in the figure. The area in red in the figure represents the range of values of the decoupling coefficient in the baseline scenario. Blue, yellow, and green are Mild low-carbon scenarios, Moderate low-carbon scenarios, and Frustrated low-carbon scenarios, respectively. Two black rays represent the critical value of different decoupling states.

Under the Business As Usual scenario, the energy consumption elasticity coefficient ranges from 0.466-0.886, of which the average elasticity coefficient is greater than 0.8 in 2015-2020 and 2040-2050, indicating that economic development will still rely heavily on energy. Under Mild low-carbon scenario and Moderate

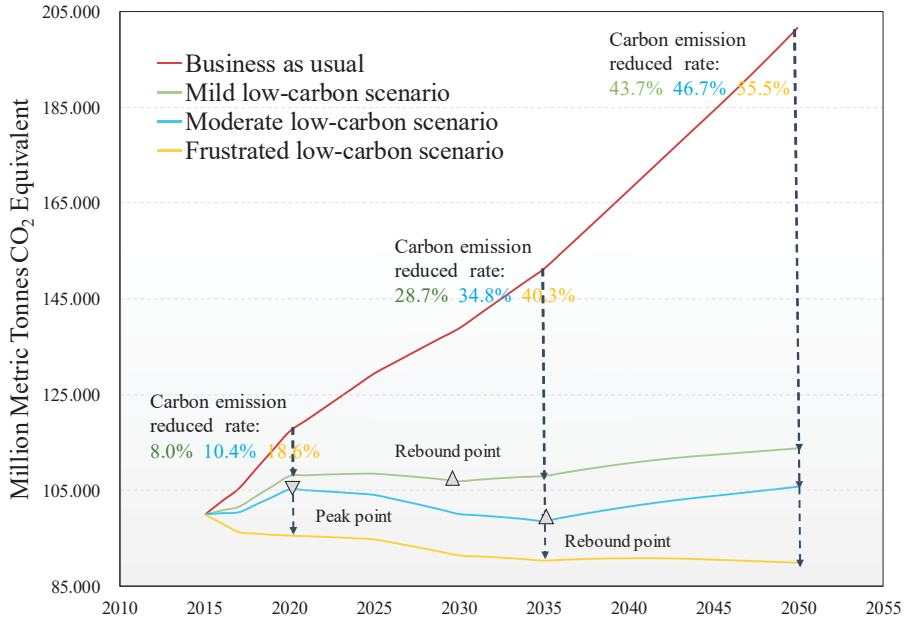

Fig. 6 Compound scenarios carbon emission changes.

low-carbon scenario, after 2025 the elastic coefficient value has stabilized below 0.3, and the whole is in a weak decoupling state. Finally, under the Frustrated low-carbon scenario, the elastic coefficient of the elastic coefficient in 2025-2030 and 2040-2050 is less than zero, and it is in a strong decoupling state. This means that under the high-intensity policy scenario, Beijing will achieve strong separation between stable economic growth and energy consumption.

4.4 Total carbon emissions

From the perspective of compound scenario carbon emissions, the three low-carbon scenarios do reduce carbon emissions compared to the baseline scenario. However, the trend of the three curves is different. As shown in Figure 6, the carbon emissions under the Mild low-carbon scenario have been relatively flat, falling after a brief peak in 2025, and steadily rising since 2029. Under Moderate low-carbon scenario, although its energy consumption has continued to rise after 2015, its carbon emissions reaches an instant peak point in 2020 and falls down since then but return to grow in 2035 and continue to grow until 2050. Total carbon emissions will reach 105.73 million metric tonnes, which is 46.7% of the baseline scenario. This shows that even after the current policy adjustment or lighter-level policy control, Beijing's carbon emissions are still likely to rebound after a peak point. It indicate that the abatement benefits brought about by other policies still cannot offset the pulling effect of economic growth on emissions. Under different strengths of the policy set, the timing of carbon emissions rebound in Beijing is also different. If Beijing wants to avoid such a rebound in carbon emissions, further adjustments is required. In Frustrated low-carbon scenario, carbon emissions continue to decline without a rebound, and its carbon emissions are predicted to be 55.5% of the baseline scenario by 2050, reducing carbon emissions by more than half.

4.5 Reduction potential of carbon emissions

The four figures contained in Figure 7 show the carbon emissions of Beijing in the next 35 years under 36 sub-scenarios. The purple lines in the last three graphs of Figure 7 represent the compound scenarios of three sectors. As mentioned above, they are obtained by superimposing B-level scenarios of different policies.

For different types of sub-scenarios, the differences of emission reduction effects among policies increase

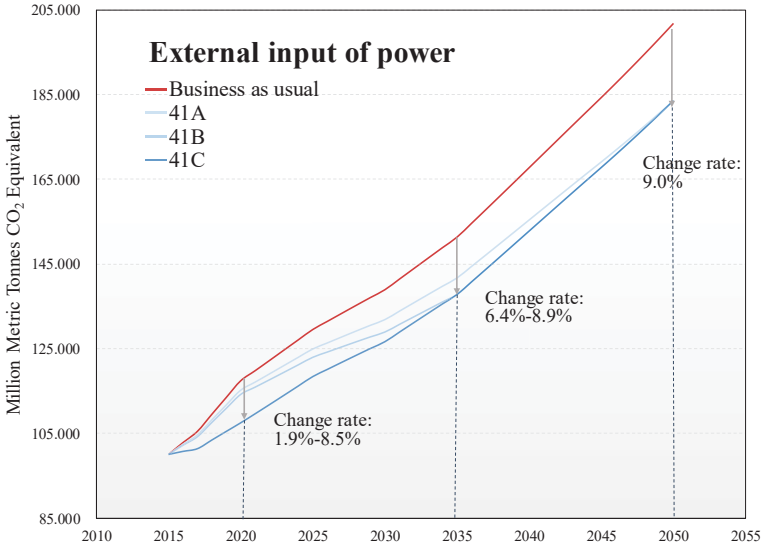

Fig. 7 Carbon emission change in external input of power scenario (41A-41C).

with time. In the top-left graph of Figure 7, for the scenarios of changing key assumption, the two major sub-scenarios show differences. In the scenarios of economic growth slowdown, the impact of adjusting intensity of GDP growth on the model results is quite different. The carbon emission reduction is between 13.66% and 3.21% of the 2050 baseline scenario. The industrial structure adjustment measures brought about by the emission reduction effect is relatively small and more concentrated, the proportion of emission reduction between 0.28%-2.54%.

The second figure shows the carbon emissions scenario of the transportation sector. From the coverage of sectoral emission reduction effects in the sector, compared with other sectors, the distribution of transportation emission reduction sub-scenarios is more concentrated and uniform. In 2035, the esteemed amount of carbon emission reductions is 0.3% to 6.5% with respect to the baseline scenario for the same year. The innovation of automotive engine technology is one of the policies with the greatest potential for emission reduction. Together with the decline in energy intensity, this could further regulate the amount of carbon emissions.

The reduction in carbon emissions from industrial emission reduction measures is between 0.6% and 9.9% of the 2035 baseline scenario. What needs to be emphasized is that within the building and transportation sector, even if the intensity of policy implementation is increased, the effect of a single measure of emission reduction is still not as good as that of the current policy. However, under the scenario of the manufacturing industry technology development (22C), the effect of emission reduction exceeds that of the compound industrial sector. Such policies worth further research and analysis.

The sub-scenarios of building emission reduction measures are more evenly distributed. In 2035, the emission reduction in the same year was between 0.5% and 9.7%. If compared with the emission reductions in the industrial sector, the potential of the building sector is not as good. However, as mentioned above, the energy saving potential of the construction sector is greater than that of the industrial sector. It has been proved that for the industrial sector, the adjustment of the energy structure is an important reason for achieving emission reductions. Scenarios 23A, 23B, and 23C have significant emission reduction effects, which confirmed this point of view again in sub-situation analysis of the industrial sector.

Scenarios for the newly proposed external green electricity policy are also included in this study. Results show that the currently planned externally-controlled green power measures have excellent emission reduction effects compared to other measures before 2030. However, their emission reduction effect is weaker than that of industry after 2035. Under the current policy intensity, from 2015 to 2050, the external green power policy can reduce 378.30 million metric tonnes CO_2 equivalent cumulatively, while the new airport and other major infras-

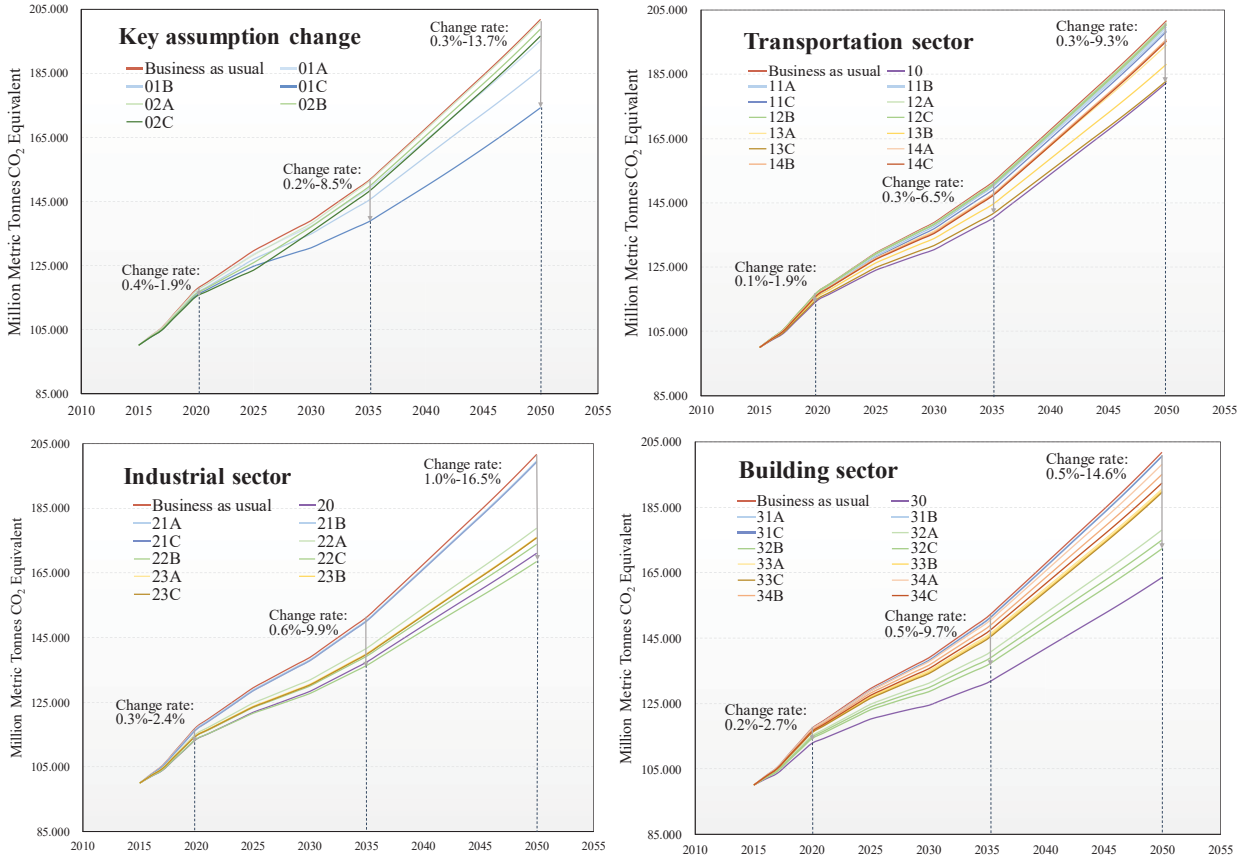

Fig. 8 Carbon emission change in sub-scenarios.

tructure construction at the same time new carbon emissions is 370.27 million metric tonnes CO_2 equivalent. Under the strategic background of the coordinated development of Beijing, Tianjin, and Hebei, the reduction of carbon emissions from the transfer of green electricity measures can completely offset the additional energy consumption of major infrastructure projects such as the new airport.

5 Discussion

Under the pressure of huge emission reductions and the need to build an international city, Beijing is facing new opportunities and challenges. In this study, carbon emissions and energy consumption of Beijing in different scenarios over the next 35 years are simulated. From the results, the three composite scenarios have better emission reduction effects, effectively slowed the pressure on energy supply in Beijing, and also played a positive role in controlling carbon emissions. Based on different intensity settings, the three curves vary with time. It worth noting that Beijing's carbon emissions should reach a maximum value by 2020 under the current policy intensity as showed in Moderate low-carbon scenario, but will continue to rebound and continue to grow form 2035 until 2050. This phenomenon may be due to the continuous and rapid growth of the economy.

The Frustrated low-carbon scenario was set up to discuss better emission reduction routes in Beijing. There is no rebound in carbon emissions under this scenario. Despite this, the future of low-carbon development in Beijing still faces many obstacles. On one hand, the setting of parameters in the Frustrated low-carbon scenario refers to the current status of foreign cities, such as Singapore, Tokyo and London. Since different cities have different stages of development, resource endowments, emissions structure and development orientation, they have obvious different regional characteristics. Therefore, it may be irrational to directly refer to the development

status of other cities. In the model, plans were made to increase clean energy such as natural gas and electricity, and reduce the proportion of coal consumption which might be optimistic. However, due to restrictions on the supply of natural resources and import and export restrictions, there is a lot of pressure on the supply system, especially with respect to natural gas and electricity. This fact poses a certain security threat to the city. This issue also worth of further study and discussion.

On the other hand, the construction of low-carbon cities requires a lot of capital investment. For example, the average marginal abatement cost of CO_2 emissions for China's thermal power sector is 316.51 Yuan/ton (Peng et al., 2018). According to the "Annual Report of Beijing Carbon Market 2017", the average price of carbon quotas in Beijing is 49.95 Yuan/ton. If calculated at this level, the city may need trillions of yuan in funding to be able to achieve the commitment defined in the "Enhanced actions on climate change: Chinese intended nationally determined contributions", which fix a cut of GDP carbon dioxide emissions, by 2030, to 60%-65% of year 2005. Therefore, funds will also limit the construction of low-carbon cities.

Future research, if combined with the abatement costs and the impact of the abatement measures on the economy, will help the choice of emission reduction paths better. In particular, along with a continuous process of models qualitative improvement and results verification, it will be important to directly monitor the emissions of critical sectors in most polluted areas of the city in order to check and improve their environmental performance. For such a purpose, innovative hierarchical approaches, integrating the use of different remote and proximal sensing platforms for intensive observation and short-term forecasts, can be applied (Casazza et al., 2013; Gargiulo et al., 2013; Casazza, 2015; Errico et al., 2015; Casazza et al., 2016; Lega and Endreny, 2016; Casazza et al., 2018). Finally, with the progress of the coordinated development among Beijing, Tianjin and Hebei, the interaction between Beijing and other cities should become more frequent. Consequently, resources and energy should be allocated to a larger area and a greater extent. Therefore, the research results on Beijing carbon emissions still have certain limitations. This is why future research should focus more on the coordinated development of this region.

6 Conclusions

In this study, 50 alternative scenarios were conceived, using the LEAP modeling tool, to represent different development pathways of Beijing's energy future from 2015 to 2050. Results show that government policies will have a significant impact on energy consumption and carbon emission. The main conclusions of this study are:

(1) Under the business as usual scenario, total energy demand in Beijing is expected to reach 208.62 Mtce in 2050, 2.8 times the 2015 level. Total carbon emissions reach 201.75 Mt-C, which is 2.0 times with respect to 2015. Without control, future energy supply systems and carbon reductions will be under tremendous pressure. Under the moderate low-carbon scenario, the carbon emission curve will drop first and then rise after 2020. Ultimately, its energy consumption will be reduced to 98.30 Mtce by 2050 and carbon emissions will be reduced to 105.73 million metric tonnes (52.9% and 55.5% decrease with respect to the baseline scenario). If the current policy measures will be well-implemented, they will play a major role in energy conservation and emission reduction for Beijing. However, carbon emission rebounded in this scenario at the point of 2035. If carbon emissions steady decline is expected, there is still a necessity to adjust current policies. In the Frustrated low-carbon scenario, Beijing's total energy demand is expected to reach 82.79 Mtce in 2050, a drop of 60.3%. Carbon emissions will be 55.5% lower than the baseline scenario, and the total carbon emissions continued to decline, effectively restraining the increase in total energy consumption and total carbon emissions, and successfully achieving the decoupling of energy consumption from the economy.

(2) From a sectorial perspective, the construction sector has become the focus for emission reduction in Beijing. Within the construction sector, the operational energy consumption of buildings, especially commercial buildings, has dominated. The industrial sector has a significant reduction effect in the early years of the forecast year, but the effect of emission reduction after 2035 is not as good as that of the construction sector. Beijing

is developing into an international transportation hub and trade center. The energy demand of Beijing's transportation sector may increase in the future, while the transportation sector has shown great potential in energy conservation and emission reduction, which should not be ignored.

(3) The future of low-carbon development in Beijing still faces many challenges. In Beijing, where energy consumption is huge and energy is heavily dependent on the outside world, there is a great potential safety risk in the supply system. How to solve the problem of stable energy supply in the process of clean energy promotion will be the focus of the next step. At the same time, in order to achieve low carbon goals, Beijing will invest a lot of money, as well as human resources, in the development of advanced energy technologies, the construction of clean and efficient energy supply systems, and the construction of infrastructure. The cost of capital will become a major constraint to the city's low-carbon development.

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The Evaluation of Forest Cultural Value Based on WTP: A Case Study in Diebu County of Gansu Province in China

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Abstract

Cultural value is regarded as an important component of forest ecosystem services, which has been received great attention to a certain extent for the relevant research in recent years. In this study, taking Diebu County of Gansu Province in China as an example, the impact factors of Willingness to Pay (WTP) of forest cultural value is analyzed by adopting Logistic Regression Model (LRM) and Contingent Valuation Method (CVM), and the value of forest culture in Diebu County is estimated. The result shows that WTP of forest cultural value in Diebu County is rather low, the percentage of people who are willing to pay only accounts for 35.29% of total survey population. Impact factors of WTP for cultural value mainly contain the education level, professional knowledge, personal income and so on, among which the impact of educational level for WTP is least, and the personal annual income is largest. In addition, the personal annual income is also the most prominent impact factor for not willing to pay for forest cultural value. Mean WTP per capita for forest cultural value of Diebu County is at the range between 18.96 RMB/a and 53.81 RMB/a. The results are calculated according to the population and number of the travelers in 2016. With the evaluation, forest cultural value of Diebu County is about between 8.2741 million RMB and 23.4390 million RMB in that year. The discussion is also raised according to relevant results in the research.

1 Introduction

Forest culture refers to a cultural phenomenon that takes forest as background or media (Su and Su, 2004). It consists of material culture, institutional culture and spiritual culture (Zheng, 2001; Liang et al., 2014). Forest culture involves not only forest aesthetics (FAO, 2004; Cai, 2002; Cardiff, 1988), forest management and utilization (Cardiff, 2000; Nonaka et al., 2012; Ghosal, 2011), forest recreation (Rahman et al., 2014; Mayer, 2014; Tyrvainen et al., 2014), but also forest aborigines therapy and so on (Herndon et al., 2009). At the international level, Germany is the first country to start the research of forest culture, which plays an important role in German culture. On the one hand, Germany's forestry theory and forestry technology research has been at the forefront of the world, and forest aesthetics research is also coming from Germany (Gendek et al., 2012; UNDP,

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2011). On the other hand, forest plays an indispensable role in the life of the German people, they regarding forest as the place to comfort and cure souls, and to gain the improvement of life style (FAO, 2004; Cai, 2002). Japan is a developed country of forestry in Asia, in the early stage, a deep study of forest culture was carried out (Cardiff, 1988, 2000). In Japan, research of forest culture has already been integrated into all aspects of daily life, such as integrated into environmental education, village and town construction, regional development and so on (Nonaka et al., 2012). Forest cultural research in India also has a long history, and shows a great difference in different periods of governance (Ghosal, 2011). In China, research of forest culture mainly focuses on cultural connotation (Su and Su, 2004), especially in an expressive manner, systematic features and so on (Kong and Li, 2005; Dan, 2002). The relevant research of forest culture in China in recent years is a tendency to its construction, communication, on traveling, regional features etc. (Chen and Zhang, 2013; Chen et al., 2014; Tan et al., 2015; Hu, 2014).

As for the value of forest culture, many people have carried out relevant researches. Many people believe that forest cultural value is an important part of forest ecological services, in which are mainly reflected in playing cultural and historical roles, especially in giving to the role of culture and history for local populations and minorities. Their experience of life and the spread of language and script etc. are important components of forest cultural values (Agnoletti and Santoro, 2015). In addition, the cultural value of the forest is also reflected in the landscape features. According to research by Vlami et al., cultural values are mainly the protection values of animal and plant habitat types, which accounts for about 67% of protected areas of Greece (Vlami et al., 2017). In the U.S., forest cultural value is often described as preferences for justice, education, freedom, and spirituality, etc. (Sills et al., 2017). Therefore, the understanding and interpretation of forest cultural value are diverse, it derived norms, beliefs, and values help drive protection for forested landscapes and forest-based benefits etc. (Sills et al., 2017).

In general, forest cultural value is regarded as the important component of forest ecosystem services in view of the relevant researches, and some researchers also pay great attention to it. However, there are not many researches on evaluation of forest culture in China, especially research one valuation through Contingent Valuation Method (CVM) is rather rare (Carson, 2012). Forest culture has externality and has the properties of public goods, of which the value cannot be directly reflected in the market. Therefore, we through a case study in Diebu county of Gansu province in China to analyze the impacting factors of forest cultural value by adopting CVM, and the Logistic Regression Model (LRM), so as to evaluate its values and provide some references for the conservation and management of forest ecosystem services, as well as to improve the management level of forest resources.

2 Data and methods

Diebu County was named as “Diezhou” in ancient time, subordinated to Zang Nationality Autonomous District of South Gansu Province, located at the eastern border of Qingzang Plateau, situating at the adjacent place of Gansu Province and Sichuan Province at the upper reach of Bailong River, often dubbed with beautiful name as “city of forest” in South Gansu Province. The total area of administrative district is 5,018.3 km^2, and forest coverage rate reaches 64.51%, vegetation coverage rate is 87%, with 1671 species of high-class plants, 183 species of rare wild life, such as panda, etc., over 130 kinds of edible wild life fungi, and 127 kinds medicine plants, which is the gene bank of about dozens of rare plants such as cuckoo in South Gansu Province, the important green ecological protective screen of the East of Qingzang Plateau, and also the important water resource conservation place in the upper reach of the Yangtze River.

Diebu County is the earliest Zang Nationality Region in China, of which religion and culture and so on have significant influence on local forest culture, and it also has very high popularity in the world. In particular, indigenous religious beliefs and cultural practices, as well as the worship of trees, have played an important role in the protection of forests. In November 1928, “National Geography” of the USA had a complete report for the folk custom and natural scenery of Zhuoni in Diebu County with 46 pages and 49 photographs. Its special

geographical location and cultural circumstance makes forest cultural contents of that county rich and colorful. However, forest cultural resource conservation is weak owing to relatively undeveloped economic development level. Therefore, it urgently needs the research of conducting forest cultural resource conservation.

2.1 Data sources

This research mainly obtains relevant data through a questionnaire survey. The questionnaire is divided into four components: individual feature, economic income situation, recognition of forest culture conservation and WTP of forest cultural value. The questionnaire includes 20 questions, and the closed topics are used in the design of the questionnaire. All questions arise in the form of selection. A brief description of each interviewee was given before the questionnaire was done. In order to improve the response rate, the questionnaire survey was conducted on a one-to-one interview. The survey time of the questionnaire is between August and September 2016, and the number of questionnaires during the survey period is 200, with 186 copies of the questionnaire response, in which 170 questionnaires are effective, the response rate of the questionnaire is 85%.

In addition, the survey is conducted through stratified sampling and random sampling for the research, aiming 12 villages and towns of the entire county, sampling mainly from Dianga Town (capital town of Diebu), Yiwa Village and Lazikou Village. As for the survey sites, it is mainly considered about population distribution, forest resource, industrial development, tourism, cultural conservation, and so on. Number of sampling is obtained through calculation by Scheaffer sampling formula (1). With assuming the error rate of sampling of people at 8% (mean of 5%-10%), the minimum number of random sampling should be 158 at least. The sample distribution is shown in Table 1.

$$n = \frac{N}{(N-1) \times g^2} + 1, \tag{1}$$

Where n is the number of samples. N is the total number of samples. g is the sampling error.

2.2 Research methods

LRM and the CVM are adopted for the research.The LRM is as follows:

$$\ln \frac{p}{1-p} = b + b_1 x_1 + b_2 x_2 + \cdots + b_n x_n. \tag{2}$$

In which, p is the probability of dependent variable y = 1, x_1, x_2, …, x_n are independent variables, n is the number of variables. To analyze the influence factors of WTP for forest cultural value, such as to be willing to pay or not willing to pay this is a typical categorical variable, and the LRM is very suitable for analyzing this kind of issue.

CVM is suitable for evaluation of the values of things that do not have market transactions. Usually, the questionnaires are used to investigate consumers' willingness to pay (WTP) and no- willingness to pay (NWTP) to show the economic value of things. Currently, there are two ways to estimate the value: The first is the Mean WTP (MWTP) method. That is by estimating general mean WTP through a sample survey. Another method is the Rate of WTP (RWTP), namely, through estimating general Mean WTP by multiplying the positive RWTP (the rate of the sum of above mean or median to WTP) to estimate the mean of total WTP (Xu et al., 2007).

(1) The formula of MWTP is:

$$MWTP = \sum_{i=1}^{k} AWP_i \frac{n_i}{N}. \tag{3}$$

In which, AWP_i is the i^{th} level of WTP, n_i is the sample number of AWP_i, N is the total number of samples.

(2) The formula of RWTP is:

$$RWTP = Mean\,(Median) \times Rate_{WTP+}. \tag{4}$$

Table 1 Samples distribution.

Survey site	The random sample (copy)	The response sample (copy)	The response rate (%)	The effective sample (copy)	The effective rate (%)
Dianga Town (capital town of Diebu)	120	109	90.83	99	90.82
Administrator	40	38	95	34	89.47
Common residents	40	34	85	30	88.24
Businessman and travelers	40	37	92.5	35	94.59
Yiwa Village	20	19	95	18	94.74
Lazikou Village	60	58	96.67	53	91.38

Table 2 The frequency distribution of WTP.

WTP (RMB yuan/a)	Frequency (copy)	Percentage of the total *WTP* (%)	Percentage of the total effective samples (%)
10	1	1.67	0.59
20	3	5	1.76
25	3	5	1.76
30	4	6.67	2.35
35	1	1.67	0.59
40	1	1.67	0.59
50	19	31.67	11.18
60	2	3.33	1.18
80	2	3.33	1.18
100	12	20	7.06
200	3	5	1.76
$>200, <500$	5	8.33	2.94
$>500, <1000$	1	1.67	0.59
>1000	3	5	1.76
Total	60	100	35.29

Notes: the percentage of the total effective samples is equal to the number of willing to pay for forest cultural value divided by the total number of effective questionnaires.

In which, *Mean* is the mean of *WTP*. *Median* is the median of *WTP* in sample survey, $Rate_{WTP+}$ is the positive rate of *WTP*. In our study, due to lack of direct market transaction price of forest culture in Diebu county, we also use *CVM* to evaluate the value of it.

3 Results and analysis

3.1 Results and analysis of WTP

3.1.1 Descriptive statistics and logistic regression analysis

In 170 effective questionnaires, there are 60 response samples are willing to pay for forest cultural value (i.e., $WTP > 0$), accounting for 35.29% of total effective questionnaires, it shows that the low ratio of *WTP* for forest cultural value. In addition, there are some differences between the payment manners, payment forms, allocation preferences, payment motivations and reasons for *NWTP* for forest cultural value. Specifically:

(1) Payment manners: Including 3 manners of payment, monthly payment, yearly payment, and one-off

payment. A one-off payment is different from annual and monthly payments. It is mainly a one-time payment of all *WTP*, and does not have to be paid at a set time in a year or a month. Three payment manners take the ratio of 15%, 13.33%, and 71.67% respectively of the total number of *WTP*. The ratio for selecting for one-off payment is largest, and the ration for the yearly payment is the least.

In addition, we can see from Table 2, it is illustrated that choose to pay 50.00 RMB is highest, is about 31.67% of the total *WTP*; the next is to choose to pay 100 RMB yearly, accounting for about 20% of the total *WTP*; and the percentage of choosing 34, 40 RMB and $>$ 500 and $<$ 1000 RMB is the smallest, is about 1.67% respectively.

(2) Payment forms: payment form mainly includes cash and tax, of which cash payment also contains pay cash to a local nature reserve or forest management agency, or donate money to a certain natural conservation fund in the country and entrust it for a special purpose only. Survey shows that most people choose cash form for the donation to a nature conservation fund for being entrusted for a special purpose only, accounting for about 21.76% of total number of effective samples; and the next comes for payment to a local forest management agency; lastly is to choose to pay by taxation, accounting for 5.88% of total effective samples (Fig. 1). It also shows that people's trust in local government agencies is not high.

(3) Payment preferences. The content of payment preference in this survey consists of four aspects: conserving local unique forest ecological system, conserving local forest special species and conducting relevant research (such as panda, black bear, snow leopard, etc.), conducting scientific research and education about local forest species, conserving local unique forest culture, tradition, customs, habit, and ecosystem, of which the proportion of total *WTP* is 28%, 27%, 25%, and 20% respectively. Concerning payment preferences, the general distribution is quite even. Among them, the payment preferences of conserving local unique forest ecosystem, conserving local forest special species and conducting relevant research, and conducting scientific research and education about local forest species are comparatively high, but the payment preference of conducting scientific research and education about local forest species, conserving local unique forest culture, tradition, customs, habit, and ecosystem is comparatively low. It accounts for only about 20% of the total *WTP*, which shows that the recognition of conservation of local forest culture is not sufficient in the local place.

(4) Payment motivations. The payment motivation mainly includes three aspects: conserving the sustainable existence of local forest culture, passing the local culture to children and descendants, and next generations to develop and utilize forest and animal resources. The selective proportion is quite even, accounting for 32%, 33%, and 35% of total *WTP* respectively.

(5) *NWTP*. The questionnaires of the responses of not willing to pay for forest cultural value, i.e., $WTP = 0$, about 110 questionnaires, is accounting for 64.71% of the total effective questionnaires. The reasons for *NWTP* are classified as 6 types. The details are shown in Table 3.

Therefore, according to the survey results, the number of choice question of "low economic income with heavy family burden and being unable to pay" is the largest, account for 40.09% of *NWTP*. The next is the choice of "uninterested in this questionnaires", accounting for 21.82% of *NWTP*.

3.1.2 Logistic regression analysis

In order to further analyze the factors affecting *WTP* for forest cultural value, we hereby adopt *LRM* to conduct analysis. As variable $Y = 1$, it means that forest cultural value is response to be willing to pay. As $Y = 0$, it means unwillingness to pay for it. The other impact factors are all explained as viable X. The details are shown in Table 4.

Firstly, SPSS software is utilized to standardize the survey data, and then the *LRM* is used for regression analysis. The results show that, among impact factors mentioned above, such as education level, professional knowledge, personal annual income, and the level of how familiar forest cultural value obviously influence the *WTP* of forest cultural value, among them $p < 0.05$, passed the statistical test, and there are statistical significance for 4 impact factors. Instead, in regression of other factors, the $p > 0.05$, which did not pass the statistical test. Therefore, they had no significant influence on the *WTP* of forest cultural value.

In addition, in order to better understand the impact degree for annual income to *WTP* for forest cultural

Table 3 The reasons of unwillingness to pay for forest cultural value.

The reasons of unwillingness to pay	Number of questionnaires	The percentage of the questionnaire of not willing to pay (%)	The percentage of the effective questionnaires (%)
(1) Low economic income with heavy family burden and being unable to pay	54	49.09	31.76
(2) Not familiar with forest cultural value and not interested about it	15	13.64	8.82
(3) Don't want to pass on the local cultural resources to children and descendants and pay for them for their generations	2	1.82	1.18
(4) Oneself away from the this region, it is difficult to share the resources, so there is no interested in it	2	1.82	1.18
(5) Forest cultural value conservation should be funded by the state, rather than individual contribution	13	11.82	7.65
(6) Uninterested in this questionnaire	24	21.82	14.12
Total	110	100.00	64.71

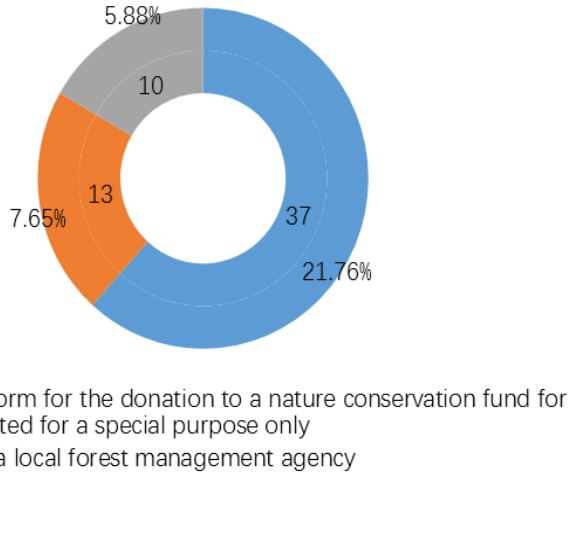

Fig. 1 *WTP* for forest cultural value - payment form ratio distribution.

value, personal annual income can be classified as three categories for analysis, i.e., x_{61} = below 5,000 RMB, x_{62} = 5,000-10,000 RMB, x_{63} = 30,000-40,000 RMB, and the results are shown in Table 5 in regression.

Therefore, according to the calculation results of Table 5, the regression equation is:

$$p = \frac{e^{(-0.79+0.64x_{45}+0.95x_{71}-0.78x_{81}-0.73x_{61}-0.61x_{62}^{+}1.01x_{63})}}{1+e^{(-0.79+0.64x_{45}+0.95x_{71}-0.78x_{81}-0.73x_{61}-0.61x_{62}^{+}1.01x_{63})}}. \tag{5}$$

In equation (5), the regression coefficient b for the how familiar level x_{8i}, the personal annual income level x_{61} and x_{62} are negative values, and the regression coefficients for the other three variables are all positive values. From the positiveness and negativeness of regression coefficients and the size of Wals values, we can see that: (1) People with the annual income is between 30,000-40,000 RMB (x_{63}), with high level education background (x_{4i}) and forestry professional knowledge (x_{7i}) are willing to pay for forest cultural value, and they also have high *WTP*. (2) People with the annual income below 5,000 RMB ($x_{61} = 0$), and 5,000-10,000 RMB ($x_{62} = 0$) are not willing to pay for forest cultural value. Therefore, from the influential degree of each factor on NWTP,

Table 4 Variable assignment table.

No.	Variables	Definition and assignment	Notes
1	Gender (x_{1i})	1 = male; 0 = female	i represents the nominal variables and k is the number of categories. (i = 0,1,... k, the same below)
2	Nationality(x_{2i})	1 = the Han nationality; 0 = minority	i = 0, 1; $k = 2$
3	Age (x_{3i})	1 = Age under 30 years old; 2 = 31 to 50 years old; 3 = 51 to 60 years old; 4 = Age older than 61	$i = 1,2,\ldots,4$; $k = 4$
4	Educational level (x_{4i})	1 = Below high school; 2 = high school; 3 = technical secondary school; 4 = junior college; 5 = above university	$i = 1,2,\ldots,5$; $k = 5$
5	Profession (x_{5i})	1 = the government administrative personnel; 2 = scientific research personnel; 3 = conservation officer; 4 = student; 5 = college teacher; 6 = enterprise or business unit worker; 7 = farmer	$i = 1,2,\ldots,7$; $k = 7$
6	Annual personal income (10000RMB/a) (x_{6i})	1 = Below 0.5; 2 = 0.5 to 1.0; 3 = 1.0 to 1.5; 4 = 1.5 to 2.0; 5 = 2.0 to 3.0; 6 = 3.0 to 4.0; 7 = 4.0 to 5.0; 8 = 5.0 to 10.0; 9 = above 10.0	$i = 1,2,\ldots,9$; $k = 9$
7	Professional knowledge(x_{7i})	1 = not familiar with the natural protection and forestry research; 2 = farmer familiar with the natural protection and forestry research; 3 = engaged in the natural protection and forestry research	$i = 1,2,\ldots,3$; $k = 3$
8	How familiar(x_{8i})	1 = not familiar with; 2 = know some; 3 = have a good understanding	$i = 1,2,\ldots,3$; $k = 3$

Source: Kong and Li, 2005.

Table 5 Logistic regression results.

Variables	B	S.E.	Wals	Sig.	Exp (B)
(1) Educational level x_{4i} (1 = Above higher education; 0 = non-higher education)	0.64***	0.23	7.86	0.01	1.9
(2) Professional knowledge x_{7i} (1 = Be familiar with the natural protection and forestry research; 0 = Not familiar with the natural protection and forestry research)	0.95***	0.34	7.68	0.01	2.58
(3) How familiar x_{8i} (1 = understanding the forest culture value; 0 = not understanding)	-0.78**	0.4	3.84	0.04	0.46
(4) Personal annual income (10000 RMB/a)x_{61} (1 = below 0.5; 0 = others)	-0.73**	0.33	5.06	0.03	0.48
(5) Personal annual income (10000 RMB/a) x_{62} (1 = 0.5 to 1.0; 0 = others)	-0.61**	0.26	5.45	0.02	0.54
(6) Personal annual income (10000 RMB/a) x_{63} (1 = 3.0 to 4.0; 0 = others)	1.01***	0.3	11.07	0	2.75
Constant	-0.79	0.24	10.37	0	0.46

Notes: *, ** and *** represents the significance level as 0.1, 0.05, and 0.01.

the factor of how familiar of forest cultural value has the least influence, of which the Wals' value is 3.84, sig. is 0.04, the significance level is less than 0,05, which mean that the significance test is passed. Similarly, the personal annual income x_{62} is at 5,000 to 10,000 RMB has the greatest influence, of which the Wals' value is 5.45, and the sig. is 0.02, less than the significance level 0.05, which also indicates that personal annual income x_{62} has a significant impact on *WTP* of forest cultural value. It also shows that different factors have different degrees of influence.

3.2 Value evaluation

According to the above study, the descriptive statistics analysis results show that the average value of *WTP* of the total effective samples of questionnaire is 53.71 ($WTP \geq 0$), the median is 0, and the standard error is 172.31. The mean value of the sample ($WTP > 0$) is 152.71 RMB, median is 50 RMB, and the standard error is 264.22. All descriptive statistical results are in the range of statistical error and can be used to assess the value of *WTP*.

According to the formula of *MWTP* (3), the *MWTP* for forest cultural value of Diebu County in 2016 is calculated as per capita 53.71 RMB /a. Similarly, according to the formula of *RWTP* (4), the *MWTP* is calculated as per capita 18.96 RMB /a. Therefore, the evaluation of *MWTP* per capita is within 18.96 RMB/a and 53.71 RMB/a in Diebu County. According to statistics, in 2016, the population of Diebu County is 436,400, including 377,000 short-term tourists. Based on the theory of cultural value evaluation (Liang et al., 2014), forest cultural value in Diebu County in 2016 is calculated about between 8.2741 million RMB and 23.4390 million RMB. This has a certain reference value to understand the forest cultural value in Diebu County and can be used to promote the development of cultural protection.

4 Discussion

Aiming for the research of the above forest cultural value, following questions are specially discussed:

(1) Forest cultural value varies at temporal and spatial scale. Forest culture contains material culture, institutional culture and spiritual culture, which are mainly reflected in real life by such as tradition, customs, religion, system, letter symbols, and faith etc. (Su and Su, 2004). As time and place change, these things are various. Therefore, when evaluating forest cultural values, the temporal and spatial scale should be considered, and the level of economic development at different temporal and spatial scale also should be taken into account, so as to objectively reflect the value of the forest culture.

(2) Above research indicates that among four major impacting factors of *WTP* for forest cultural value, the personal annual income has the greatest impact. The impact of educational level and professional knowledge is middle, and the influence of how familiar of forest cultural value is the least. Therefore, when evaluation the forest culture value, we should focus on improving the personal annual income level, enhancing education level improvement, popularizing the relevant professional knowledge on forests etc. This is an effective way to increase the *WTP* of forest culture, and it is also the main approach to raise the forest cultural values.

(3) At present, the *CVM* is mainly adopted for evaluation forest cultural value in the world (Zheng, 2001), however, there is a big debate about it, and it needs to improve the questionnaire design, the choice of sampling method, etc. urgently so as to improve the scientific evaluation results. *CVM* is a kind of professional evaluation method for valuation of non-market trading resources. It needs professional staff to design the questionnaire and investigation. Therefore, when evaluation forest cultural value the investigators must be professionally trained, and did a large number of comparing case studies. In particular, comparing case studies of various situations around the world should be focused. That's where we're going in the future.

5 Conclusions

In this paper, we estimated and calculated the values of forest culture in Diebu County of Gansu province in China according to the *LRM* and *WTP*. The result of research shows that:

(1) The *WTP* for forest cultural value in Diebu County in 2016 is quite low, the number of persons willing to pay accounts for 35.29% of the total survey number of people. Thereof, the number of persons who choose to one-off payment accounts for 71.67% of total effective questionnaires. The number of persons who choose cash form for the donation to a nature conservation fund for being entrusted for a special purpose only, accounting for about 21.76% of total number of effective samples. Meanwhile, due to the low economic development level of

Diebu County, the personal annual income, education level and professional knowledge level become the main impacting factors of *WTP* for forest cultural value.

(2) Among the impacting factors of *WTP* for forest cultural value in Diebu County, the factor of the how familiar level of forest cultural value is the least one, while the factor of personal annual income level and education level is the greatest one. This is very important in development and education of forest culture conservation. It is an effective way to increase the *WTP* of forest culture, and a main approach to raise the forest cultural values.

(3) People have willingness to pay for the forest cultural values at different temporal and spatial scale. In Diebu County of Gansu province, the range of *MWTP* is estimated between 8.2741 million RMB and 23.4390 million RMB in 2016. This has a certain reference value to promote and manage the forest cultural industry in local place.

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Audit Judgment Performance: The Effect of Performance Incentives, Obedience Pressures and Ethical Perceptions

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Abstract

This study aims to analyze the influence of performance incentives, obedience pressures and ethical perceptions to audit judgment in auditors' professional activities. Data collection was conducted by distributing questionnaires to auditors from public accounting firms in Indonesia. The result showed that the performance incentives increase the performance of audit judgment. The obedience pressures of auditors profoundly influenced the performance of audit judgment performance of auditors whereas the ethical perception has no effect on audit judgment. This study suggests that auditors should pay attention to auditing standards and professional codes of ethics, encourage auditors to be able to overcome the pressures and behave by the professional ethical standards. Therefore audit firms should provide performance incentives. Finally, the study shows that the Institute of Public Accountants Indonesia (IAPI) is expected to always conduct continuous professional education (PPL) for the audit profession in order to implement the audit standards and professional code of ethics.

1 Introduction

Auditors should exercise professional judgment in planning and auditing financial statements according to the standards of the Professional Standard of the Public Accountant (SPAP, 2014; IAASB, 2014). In this matter, professional judgment in conducting an audit is very important as mentioned by SPAP (2014) audit standard in section 100. Unprofessional audit judgment can lead to a misstatement of financial audit (Arens et al., 2014; Wyatt, 2014).

Auditors' professional judgment is influenced by three groups of factors namely task factors, environmental factors and personal factors (Meyer, 2001; Bonner and Sprinkle, 2002). The task factors consist of the composition of information, the relevance of information and the complexity of the tasks. Environmental factors consist of pressures, feedback, regulations and standards while personal factors consist of knowledge, skills, abilities, gender, culture and moral development (Bonner and Sprinkle, 2002; Iskandar and Sanusi, 2011; Aswathi and Pratt, 1990; Baeley et al., 1998).

Professional judgment is the result of a collective assessment in all phases of audit activities which include audit planning, gathering, evaluating of audit evidence, and reporting of the audit opinion. In conducting audit

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judgment, auditors are required to identify the audit objective, analysis of material level, evaluate the audit risk that is related to audit planning and makes the appropriate audit opinion. The quality of judgment and decision made will determine the auditors' work quality (Watkins et al., 2004).

According to Bonner and Sprinkle (2002), and Sanusi and Iskandar (2007), performance incentive is a kind of environment variable that could affect individual efforts and audit judgment performance. Performance incentives are employees' financial incentive in the form of bonuses, commissions as rewards for employee performance (Watkins et al., 2004). Therefore the performance incentive can be treated as an environment variable that could influence the performance of the audit judgment. Several studies are in line with the statement on incentive and effort which could determine the influence of performance incentive on the auditors' performance quality (Bonner and Spilker, 2002; Aswathi and Pratt, 1990; Bonner and Spilker, 2002; Baeley et al., 1998). However, Libby and Lipe (1992), Aswathi and Pratt (1990) and Libby et al. (1992) showed that financial incentives have no significant effect on audit judgment.

Obedience pressure is an increasing social influence pressure on the individuals who receive a direct order from other parties (Brehm and Kassin, 1990; Lord and DeZoort, 2001). Previous studies (Lord and DeZoort, 2001 and DeZoort and Lord, 1994) stated that obedience pressure influence significantly the auditors' professionalism in making the judgment. However, several studies (Putri and Laksito, 2013; Hartanto and Kusuma, 2002) revealed that obedience pressure has no significant effect on audit judgment. In other researches, Tielman (2012), Praditaningrum and Januarti (2012) showed that obedience pressure has a negative and significant impact on audit judgment. Pressure from a superior or client can also exert bad influences such as loss of professionalism, loss of public confidence and social credibility.

Auditors from the public accounting firms should pay attention to ethics in performing their duties. Ethics the issue is important to convince clients and external users about the quality of the audit performed (Espinosa and Barrainkua, 2016; Arifuddin, 2014; Nugrahanti, 2012; Sweeney and Roberts, 1997). Hence, public confidence in the quality of professional services will increase as the auditing profession fosters high standards of performance and ethics (IESBA, 2014; Arens et al., 2014; SPAP, 2014). Recently, there are increasing numbers of studies about the influence of these factors towards audit judgment performance and also more accounting practitioners are interested in investigating individual behaviour behind audit judgement (Espinosa and Barrainkua, 2016).

Based on the above explanation, the research issue is whether there are influences of performance incentives, obedience pressures and ethical perceptions toward audit judgment performance. Thus, the objectives of this study are to test empirically and analyze the influence of performance incentives, obedience pressures and ethical perceptions toward audit judgment performance.

2 Literature review and hypotheses development

2.1 Audit judgment performance

Audit judgment is an audit procedure performed by the auditor to make consideration and evaluation for the fairness of the financial statements (Bonner, 1999; DeZoort et al., 1994; Hogarth, 1992). An auditor is required to collect valid evidence of data and information of the corporation's financial statements to create a relevant, reliable and independent auditor's professional judgment (Hogarth, 1992; Bonner, 1999; DeZoort et al., 1994). In the audit works, the auditor's professional judgment would determine the audit judgment (Gibbins, 1984). The quality of judgment and the decision made are the reflections of the auditor's work quality (Watkins et al., 2004).

2.2 Performance incentives

Audit firms often use performance incentives to improve the performance of auditors as a whole. The most commonly used performance incentives are financial and nonfinancial incentives (Iskandar dan Sanusi, 2012).

Financial incentives can drive people to seek the skills they need to perform tasks so their future performance and consequently their compensation will be better (Sanusi and Iskandar, 2007; Bonner and Sprinkle, 2002). Earlier studies stated that financial incentives (for example, commission, bonuses) and nonfinancial incentives (for example, facilities, promotions) could improve auditor performance in auditing financial statements (Aswathi and Pratt, 1990; Bonner and Spilker, 2002; Baeley et al., 1998; Sanusi and Iskandar, 2007). Bonner and Spilker (2002) mentioned the importance of performance incentives to motivate auditors in conducting audit judgment. The incentives are based on the cost of living and the income level of the auditors (Bonner, 1999).

According to Ashton et al. (2002), financial incentives could improve performance tasks and audit judgment performance as well. Similarly, Sanusi and Iskandar (2007) agree that audit judgment performance is influenced by performance incentives. The feedback information about performance and efficiency can also improve the performance of audit judgement as revealed by some studies (Earley, 1990; Ashton, 1990; Iskandar dan Sanusi, 2012). Therefore, the following hypothesis was proposed:

H1: Performance incentives influence audit judgment.

2.3 Obedience pressures

The theory of obedience states that the individual who has power is a source of influence to others due to the existence of authority or legitimate power towards a subordinate because of the organizational hierarchy (Brehm and Kassin, 1990; Lord and DeZoort, 2001). Milgram (1974) has developed power obedience paradigm which stated that subordinates will experience a psychological change because of their superior's pressure. Lord and DeZoort (2001) and DeZoort and Lord (1994) found that normal people can commit destructive actions when faced with enormous pressure from legitimate authorities. These findings are consistent with the studies conducted by Brehm and Kassin (1990), Lord and DeZoort (2001), DeZoort and Lord (1994). They stated that the greater the pressure faced by auditors, the greater the dilemma faced and ultimately judgment mistakes may occur, whether intentional or not. This finding is reinforced by those of DeZoort and Lord (1994) who saw the effects of superior pressures were costly consequences such as lawsuits, the loss of professionalism, the loss of public confidence and social credibility.

The findings above proved that the performance of auditors in conducting audit judgment is affected by the pressure of obedience. In another previous research showed that obedience pressure in the form of the superior commands and the demand of the client to deviate from the professional standard will tend to encourage auditors to violate the professional standard (Lord and DeZoort, 2001; DeZoort and Lord, 1994). Thus, it can be concluded that obedience pressures affect audit performance in making audit judgment. Therefore, the following hypothesis is was proposed:

H2: Obedience Pressure is influential in making audit judgment.

2.4 Ethical perceptions

Ethics as a moral teaching is not written but for a professional organization, ethics are outlined in a written code called code of ethics. Code of ethics is a system of moral principles that is established by a group of professionals (Arens et al., 2014; Wyatt, 2004). The auditor's code of ethics is made to serve as a rule of ethical conduct for professional members aimed at maintaining the reputation and trust in the community (IESBA, 2014; SPAP, 2014).

Indonesia Accountant Association (IAI) has a code of conduct that binds its members. In order to become a public accountant that can be trusted by the community; accounting profession practices must adhere to the ethical principles as contained in the Code of Ethics of Public Accounting Professional Indonesia (SPAP) in section 100 (2014), covering (1) Responsibility of the profession, (2) Public interest, (3) Integrity, (4) Objectivity, (5) Competence, precision and precautions, (6) Confidentiality, (7) Professional Behavior and (8) Technical Standards. The results of research conducted by Sweeney and Roberts (1997); Nugrahanti (2012), Arifuddin (2014) and Espinosa and Barrainkua (2016) concluded that ethical perceptions affect the professional judgment of auditors. Thus, the following hypothesis was proposed:

H3: Ethical perceptions have an effect on the creation of an audit judgment.

3 Methods

The population in this study are the auditors who work in public accounting firms or *Kantor Akuntan Publik* (KAP) in Indonesia, the accounting firms from the big four and non-big four of small and medium size, or accounting firms in collaboration with foreign parties. The auditors who participated in this research are at any of the following levels of auditor partner; auditor manager, auditor supervisor or senior auditor whose responsibility is to conduct the audit. Sampling technique used was purposive sampling, whereby samples were obtained at any time on condition that the sample was suitable to specific criteria.

The type of data used in this study is the primary data and the survey method was used to collect data. A total of 178 survey questionnaires were distributed to auditors of KAP selected randomly from a list of KAP registration in the Institute of Accountants Public Indonesia. The number of completed questionnaires were 77 and 70 questionnaires were used for the analysis.

The limitations of this study are: (1) when distributing the questionnaires, it was found that many respondents were out of town on duty which limits the number of completed or returned questionnaires, (2) the external validity of this study is limited since the casein the questionnaire contains less information than the actual state of the audit environment. In an actual audit situation, richer information will influence audit judgment performance.

The measurement of audit judgment performance is conducted through the number of correct responses compared with standard criteria. The evaluation of audit judgment performance is based on the number of correct substantive and compliance tests listed. The respondents need to identify substantive tests of transactions that are likely to uncover the misstatements created in the audit case. The quality of work was appraised by the correct responses from each audit task in the questionnaire and the more correct responses given by the auditors shall be interpreted that the auditors' work would be more qualified (Bonner, 1999; DeZoort et al., 1994; Gibbins, 1984, Hogarth, 1992; Watkins et al., 2004).

The measurement of the independent variable; performance incentive was by the number of bonuses, commissions, promotions and grant facilities that the auditors received from the employer and the level of incentives given in auditing the financial statements (Sanusi and Iskandar, 2007; Bonner and Spilker, 2002; Aswathi and Pratt, 1990; Bailey et al., 1998; Iskandar and Sanusi, 2012).

The independent variable; pressure obedience from a senior auditor, a superior or to a junior auditor, and the pressure that from the client were examined to identify deviations against predetermined standards by DeZoort and Lord (1994), Brehm and Kassin (1990), and Lord and DeZoort (2001). The obedience pressure was measured by an instrument consisting of nine-question items. The measurement scale used was a five-point Likert scale ranging from *strongly disagree (5) to strongly agree (1).*

The independent variable; the ethical perception was measured by the ethical principles that auditors must exhibit in auditing judgment which includes professional responsibilities, public interest, integrity, objectivity, competence, precision, prudence, confidentiality, professional behaviour and technical standards (SPAP, 2014; Sweeney and Roberts, 1997; Espinosa and Barrainkua, 2016; Arifuddin, 2014; Nugrahanti, 2012). The pressure of obedience was measured by an instrument consisting of twenty one-question items. Respondents indicated their degree of agreement or disagreement with each statement using a five-point Likert scale.

The results were statistically analyzed using multiple regression analysis. The model is formulated as follows:

$$Y = a + b_1X_1 + b_2X_2 + b_3X_3 + e \quad (1)$$

where Y is audit judgment performance, a is the value of intercept (constant), $b_1 - b_3$ is the regression coefficient, X_1 is performance incentives, X_2 is pressure obedience, X_3 is the ethical perception, and$e$ is an error. The significance level used is 1% or 5% or 10% (Ghozali, 2013).

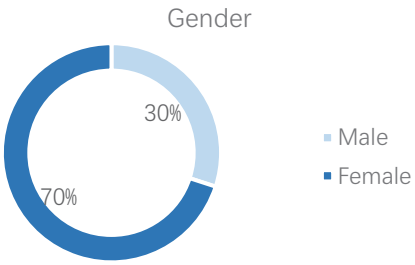

Fig. 1 Gender of Respondents.

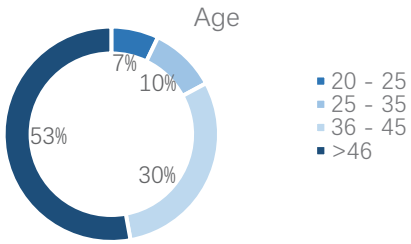

Fig. 2 Age of Respondents (Years).

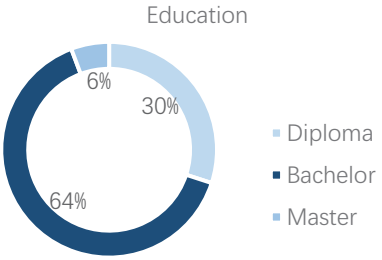

Fig. 3 Tertiary Education of Respondents.

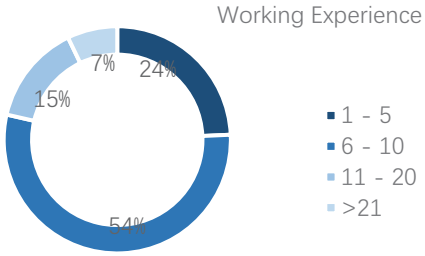

Fig. 4 Period of Working Experience (Years).

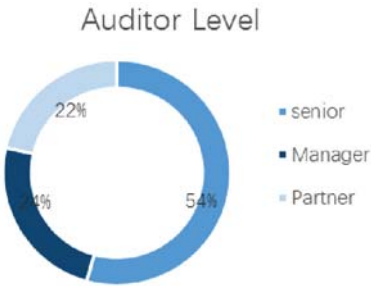

Fig. 5 Status of Respondents.

4 Results

4.1 Demographics of respondents

The demography of the 70 respondents consisted of 21 males (30%) and 49 females (70%) with a majority between 36 years old and 45 years old (35%). The tertiary education of 45 respondents (64%) is mostly with a bachelor degree. The longest period of working experience in audit works is between 6 to 10 years (54%) and 15 respondents (22%) are holding a position as an auditor partner.

The descriptive statistics of this study in Table 1 shows that the minimum value for the performance incentive variable is 20 and the maximum is 30 with an average total of 25.54 and a standard deviation of 2.652. As to the minimum values for obedience, the pressure variable is 24 and the maximum is 41 with the average total of 29.96 and the standard deviation of 3.286. With the ethical perception variable, the minimum value is75 and the maximum is 103 with a mean total of 90.41 and standard deviation of 5.213, while the audit judgment variable minimum value is 18 and maximum 40 with an average total 32.24 and standard deviation equals to 4.448.

Table 1 Descriptive statistics.

	N	Minimum	Maximum	Mean	Std. Deviation
Performance_ incentives	70	20	30	25.54	2.652
Obedience_ pressure	70	24	41	29.96	3.286
Ethical_ perception	70	75	103	90.41	5.213
Audit Judgment	70	18	40	32.24	4.448
Valid N (listwise)	70				

Table 2 Test Result of Multiple Linear Regression Model.

Model	Unstandardized Coefficients		Standardized Coefficients	t	Sig.
	β	Std. Error	Beta		
(Constant)	39.174	6.456		6.068	.000
Performance_incentives	.781	.131	.466	5.958	.000
Obedience_pressure	.570	.106	.421	5.367	.000
Ethical_perception	-.486	.066	-.570	-7.340	.127

Note: Dependent Variable: Audit Judgement Performance

4.2 Validity and reliability test results data

All indicators used to measure all variables in this data are valid. The validity of test results for each of the variables have a correlation coefficient greater than r-table for $n = 70$ is 0.2352, so all the indicators for these variables are valid (Ghozali, 2005). Internal consistency of the items related questions to the variables in this study is indicated by Cronbach's alpha coefficient greater than 0.7. It means that all questions from each of the variables were reliable (Ghozali, 2005).

4.3 Classical test assumptions

Testing normality of data was done using the Kolmogorov test; where the value of Kolmogorov-Smirnov of 0.978 and not significant at 0.05 or above were 0.05 (p=0.978 for $>$ than 0.05). So we cannot reject H0, which means that the residuals were normally distributed. Test results multicollinearity data shows that all independent variables had tolerance values above 0.10 and VIF values were under 10. It means that the regression model is free of multicollinearity problems. Heteroscedasticity test results obtained with the scatter plot that there are points that spread the field scatter. It means that the model of regression in this model does not contain a problem of heteroscedasticity.

4.4 Hypotheses testing

Table 2 shows the regression analysis results of performance incentives, ethical perceptions and obedience pressures on audit judgment performance. Regression equation model was based on *Moderated Regression Analysis* (MRA).The result of the research model is as follows:

$$Y = 39,174 + 0,781X_1 + 0,570X_2 - 0,486X_3 + e. \quad (2)$$

Table 2 shows the audit judgment variable has a constant value of 39.174 with a positive result. The result means that the constant value was not affected by performance incentive, obedience pressure or ethical perception variables. The table also shows that β_1 performance incentives have a coefficient value of 0.781 with a positive sign and this means that performance incentives have a positive effect on audit judgment. In other words, any addition of performance incentives obtained by the auditors will raise the quality of audit judgment.

Table 3 Statistical test results t.

Model	Unstandardized Coefficients β	t	Sig.
N (*Constant*)	39,174	6.068	.000
Performance_incentives	.781	5.958	.000
Obedience_pressure	.570	5.367	.000
Ethical_ perception	-.486	-7.340	.127

Table 4 Statistical Test Results FANOVA[a].

Model	Sum of Squares	D_f	Mean Square	F	Sig.
Regression	851.387	3	283.796	36.477	.000[b]
Residual	513.484	66	7.780		
Total	1364.871	69			

Note: a. Dependent Variable: Audit Judgement Performance, b. Predictors: (Constant), Performance_incentives, Obedience_pressure, Ethical_perception

Table 5 Coefficient of Determination (R_2).

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Durbin-Watson
1	.790[a]	.624	.607	2.789	2.005[b]

Note: a. Predictors: (Constant), Performance_incentives (X_1), Obedience_pressure (X_2), Ethical_perception (X_3),

b. Dependent Variable: Audit Judgement Performance (Y)

β_2 obedience pressure has a coefficient of 0.570 with a positive sign which means that the obedience pressures has a positive effect on audit judgment. The positive sign indicates that each addition of an obedience pressure to the auditors will further improve the quality of audit judgment.

β_3 ethical perception has a coefficient of 0.486 with a negative sign indicating that ethical perception has a negative effect on audit judgment and that any decrease in an ethical perception toward the auditors will further decrease the quality of audit judgment.

As indicated in Table 3, the criterion for t-test (partial) is if its probability (significant) = 0.01 or = 0.05 and or = 0.1 H_a is rejected and its reversal if probability (significance) > 0.01, > 0.05 and > 0.1 then H_a is accepted.

The first hypothesis (H_1), referring to the t-test above shows the performance incentives (X_1) variable on audit judgment performance (Y) has a significance value of 0.000 that which is smaller than 0.01 (0.000 <0.01) with coefficients (β) 0.78. The result means H_o is rejected and H_a is accepted and that conclude H_1 is accepted. It means that performance incentives have a significant positive impact on audit performance. With this result, it is concluded that auditors who received performance incentives will be motivated to produce audit judgment performance better than auditors who do not receive performance incentives (Bonner and Sprinkle, 2002; Iskandar and Sanusi, 2012).

As for the second hypothesis (H_2), the result of testing the influence of obedience pressures (X_2) on audit judgment performance (Y) has shown a significant value of 0.000, that is smaller than 0.01 (0.000 $<$ 0.01) with the coefficient (β) 0.570. This result indicates that H_o is rejected and H_a is accepted, and it can be concluded that H_2 is accepted which means that obedience pressure has a significant positive impact on audit judgment performance. This result means that the higher the obedience pressures faced by the auditors from both the employer and the client, the further it will improve the quality of the audit judgment performance presented by the auditor (Brehm and Kassin, 1990; DeZoort and Lord, 1994; Lord and DeZoort, 2001).

The third hypothesis (H_3) indicates the ethical perception (X_3) effect on audit judgment performance (Y).

The result of data processing shows the regression coefficient on ethical perception relationship and audit judgment performance is equal to -0.486 has significance value equal to 0.127 that is bigger than 0.10 ($0.127 > 0.10$) with coefficient showing the direction is opposite to audit judgment performance that is ethical perception. The result indicated H_o is accepted and H_a is rejected. It can be concluded that H_3 is rejected. Ethical perception has no significant effect on the negative direction of audit judgment performance. It shows that the low ethical perceptions possessed by the auditors do not affect the audit judgment. This study revealed that ethical perceptions have no significant effect on audit judgment which is in line with previous studies (Putri and Laksito, 2013; Hartanto and Kusuma, 2002).

Based on Table 4, results of testing the overall model F-test obtained with the F value of 36.477 with a significance of 0.000. Thus, testing a model using the variables of performance incentives, obedience pressures and ethical perceptions can be demonstrated as significant to the audit model judgment performance. Based on Table 5, the magnitude of the influence of the three independent variables are indicated with an adjusted coefficient of determination R_2 value of 62.4% per cent of audit judgment performance which can be explained by the variables of performance incentives, obedience pressures and ethical perceptions as the remaining 37.6% of audit judgment performance explained by other variables not included in this model.

5 Discussions

5.1 The influence of performance incentives on the professional audit judgment

Performance incentives can increase auditors' productivity and determine the audit judgment. It indicates that the auditors who obtain financial incentives from the KAP will produce better judgments resulting in more responsible auditors carrying out their audit duties. The result is in line with studies conducted by Aswathi and Pratt (1990), Bonner and Sprinkle (2002), Sanusi and Iskandar (2007) and Baeley et al. (1998). They stated that performance incentives are a form of financial rewards of bonuses, commissions for employees' performance. Thus, performance incentive is a variable that can affect individual performance and audit judgment.

5.2 The influence of obedience pressure on the professional audit judgment

Auditors with high obedience pressures will have a high sense of responsibility in accomplishing their duties. The high sense of responsibility for the implementation of these tasks encourage the auditors to cope well with the pressures of compliance and have an effect on the quality of audit professional judgment. Consequently, auditors can make quality audit judgment. These results support the research by DeZoort and Lord (1994), Brehm and Kassin (1990) and Lord and DeZoort (2001) that the auditors under superior orders and pressures from clients who do not deviate from professional standards tend to cause junior auditors to obey the command.

5.3 The influence of ethical perceptions on the professional audit judgment

The personal factor of the auditor's ethical perception affects the auditor's professional judgment. High ethical perceptions would encourage an auditor to behave by ethical standards thereby increasing the professional judgment. On the contrary, the findings of this research indicated that low ethical perceptions do not influence in reducing the quality of audit professional judgment (Putri and Laksito, 2013; Hartanto and Kusuma, 2002).This is due to differences in the competence and professional responsibilities of the male and female auditors in interpreting and understanding the ethical perceptions about existing practices of the cultural values of the country.

Public trust in the quality of audit services will increase when the public accounting profession encourages high performance and ethical standards to all auditors so that a good ethical perception will be able to positively influence auditors' professional judgment (Bonner and Spilker, 2002; Sanusi and Iskandar, 2007; Aswathi and Pratt, 1990; Bailey et al., 1998).

6 Conclusion

Hypothesis test results indicated that performance incentive is one of the variables that can affect individual performance and audit judgment performance. This study shows that Indonesian auditors who received performance incentives from public accounting firm (KAP) will be able to improve audit judgment performance better than auditors who do not receive incentives. Furthermore, the higher obedience pressure faced by auditors both from the pressure of the superior and the client, the further it will improve the quality of audit judgment performance. However, the ethical perception has no significant negative effect on the audit judgment performance which means that low ethical perceptions by the auditors do not result in a decrease of the quality of audit judgment in their professional activity.This study will provide the following benefits: (1) Auditors can improve their performance in carrying out audit tasks and need to pay attention to auditing standards and professional codes of ethics; (2) Public accounting firm (KAP) could improve audit quality by providing performance incentives for employee achievement, encouraging auditors to overcome the pressure and always behave in accordance with the professional ethical standards; (3) Institute of Public Accountants Indonesia (IAPI) is expected to always socialize the implementation of audit standards and apply the professional code of ethics through Continuing Professional Education (PPL). Future studies are recommended to develop research models by adding some variables, such as gender aspects, experience, knowledge, profession, responsibility, ability, independence and task complexity.

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A Simulation Approach to Understanding The Effect of Mimicry on Prey's Flourishing When Predators Decline Due to Environmental Disturbance

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Abstract

Ecological interactions and their consequences to system evolution in the context of environmental disturbance are of special concern in ecological conservation since the environmental conditions have been changing so quickly in the past decades. Understanding how these interactions, particularly the indirect ones such as mimicry, could change prey variabilities in facing of predator loss is an interesting question. In this research, we incorporated Batesian mimicry into a three-species predator prey system to investigate the role of mimicry on regulating prey abundance when the system is suffering predator loss in various patterns. The Netlogo mimicry model was adopted to run the simulation experiments. We found that the timing of predator loss interacting with mimicry can induce significant difference in mimic prey's abundance if partial predators were removed from the system. However, the variations of frequency of predator loss did not change the mimic prey's abundance in all conditions. Our findings suggested that indirect interactions can change the final species composition on the long term evolutionary scale if environmental disturbances occur in the particular time window. This is the first report that addresses the question of how indirect interactions such as mimicry affects species abundance when environmental disturbance occurred. We expect that this finding could shed the light on conditions under which species and ecological balance can be better managed when environmental disturbances are inevitable to come.

1 Introduction

Predation, a "top-down" force in nature rules ecosystems for millions of years (Fraser, 2011). However, in contrast with photosynthesis and nutrient cycling, the importance of predation had been underestimated by ecologists for a long time until a scientific consensus was emerging that predators are critical to the formation of feedbacks that control and regulate the ecosystem (Berger et al., 2001). The reality of predator loss is far worse than what we can intuitively perceive, e.g., not just feeling how awful to never again see such a creature. Because the disappearance of predator, extinction or even just reduction in numbers, is irreversible and likely to cause cascade disasters across food webs and ecosystems (Dunne and Williams, 2009). In recent years, considerable evidences of damage to ecosystem by predator reduction have been shown (Zdilla, 2010), for

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example, overfishing of cod in the costal North Atlantic caused uncontrolled and hyper-abundant lobster and sea urchins, which has been the primary threat to the biodiversity in the Gulf of Maine (Steneck et al., 2013).

Understanding how predator disappearance would affect the population size of its preys is critical and the primary step to protect biodiversity and avoid potential threat to ecosystems. It has been widely accepted that predator disappearance is likely to flourish preys (Zeckhauser, 2017), but could different types of disappearance event make difference in the growth of the prey population? Generally, the disappearance of a species occurs gradually in nature because of the large population existing as well as the large spatial scale it can reach (Graham et al., 2000). However, due to the climate change and overdevelopment of human society in recent years, the events of rapid disappearance become more common than ever, especially in the case when the environmental conditions change more rapidly than the species can adapt (Sahney and Benton, 2008). Therefore, the disappearance of predator can be varied in amount and time (Rowland, 2009), e.g., the amount of predator could decline gradually in a relative long period or suddenly decrease in a time point, which is known as gradual disappearance or rapid disappearance. In addition, predator may not only be reduced in numbers, the event of disappearance could happen any time during the long-term evolution process of the ecosystem, which means the timing of disappearance might be another potential factor that affects system dynamics.

Indirect interactions between preys are potential forces shaping preys population (Lang and Benbow, 2013). For instance, mimicry, the similarity of one prey (mimic species) in appearance to another (model species) plays an important role to gain protection in facing the common predator species (Maynard-Smith and Harper, 2004). The variation of mimic species as well as the traits of predators would be potential factors that change the population of mimic preys (Wickler, 1968). The higher the mutation rate of the mimic prey, the more likely they shift their appearance approaching the model species, which in turn enhance the mimic population density. The perceptibility of the predator might also be important to mediate the indirect interactions between preys. When a predator has a good memory, it can hold the yucky feeling much longer after eating an unpalatable prey. Then the mimic species is well protected. Therefore, we would expect that mutation and memory are two key factors regulating mimicry that poses indirect interactions between prey populations.

The primary goal of this research, was to understand whether gradually and rapidly disappearance of predators could make difference in flourishing prey population. Then, we aimed at testing the effect of timing of predator disappearance on prey population dynamics. In addition, we were interested in whether mimicry plays an important role in regulating these effects. To bridge this gap, we used simulation approach based on a spatially explicit mimicry model (Wilensky, 1997) on NetLogo simulation platform (Wilensky, 1997) to test the hypotheses and discussed what we found. Current models that used to investigate dynamics in predator-prey system are mostly based on the differential equation Lotka-Volterra model (Yorke and Anderson, 1973). The deficits of this type of model are (Deangelis and Mooij, 2005): 1) they works on population level and provide no individual level traits, which is the major obstacle to model individual specific behaviour such as perception, memory and learning; 2) they are very difficult to present spatial heterogeneities, which are very common in nature and probably the potential factors that affect model results; and 3) the more species in the model, the higher the complexity in modelling and analysing. These are primary reasons that we chose the spatially explicit model, which is easy to implement and able to incorporate stochastic and individualized behaviour (Devaurs and Gras, 2010; Belvisi and Venturino, 2013).

Although the research questions emerged from this paper have not been directly reported around the ecological and environmental community, we do have seen some related works which are focusing either on evolution and environmental disturbance or mimicry itself. Ponge (2013) developed a theoretical model to compare the adaptability of two groups of organisms under environmental changing pressure. Long term evolutionary divergence in adaptively of the two groups has been clearly shown. One group with better energic optimization ability tends to perform well in stable environment, whereas the other group without energic optimization strategy (i.e., using energy in foraging, growth and reproduction) adapted well in unpredictable environment. A theoretical model proposed by Kokko et al. (2010) showed interesting result that alternative prey can change model mimic dynamics between parasitism and mutualism. This model revealed that both mutualistic and par-

asitic relationship between model and mimic are possible and the availability of alternative prey can easily alter this relationship. In order to understand the condition for the persistence of mimicry, Seno and Kohno (2012) suggested a mathematical model of population dynamics for Batesian mimicry system. The model introduced a new concept of searching image based on predators' experience. They found that mimicry persistence mainly depends on predators' memory instead of the population size of the mimic species. These models are important to investigation of mimicry and evolution. However, they did not directly address the scientific questions that we are going to explore in this research.

In this paper, we firstly introduced the three-species predator-prey model with mimicry and how it works in a spatially explicit manner. Then, we described the simulation experiments and parameterization. Finally, the simulation results were analysed, and findings were discussed with conclusion.

2 The model

The model we used in our research is the famous mimicry simulation model developed by Wilensky (1997) on NetLogo simulation platform. We chose the NetLogo mimicry model not only because it is totally free and of its spatial explicit features, but also based on the following reasons. First, the NetLogo mimicry model established an excellent evolutionary framework under which all elements of mimicry such as individual appearance, memory and learning can be parameterized, and the system dynamics can be readily observed over time. This facilitation could be very helpful to focus our efforts on modelling logic instead of coding. Second, the NetLogo mimicry model has been widely accepted and cited by the ecological and environmental research community. The firmly grounded model could significantly reduce the uncertainty and bias in building a model from scratch. Third, all models in NetLogo simulation platform provides source code that allows us thoroughly understanding the model logic, from which we can adapt the model to our researches with necessary revisions.

The model contains one predator species, birds, and two prey species, monarchs and viceroys which are respectively butterflies and moths. Monarchs are fed with toxic milkweed thus they taste yucky and are inedible to birds. However, viceroys are harmless and palatable to birds. Technically, monarchs and viceroys are unrelated species but share with highly similar appearance probably due to long term evolution. This the so-called Batesian mimicry in which the palatable species (the mimic) take advantage of the visual similarity with the toxic species (the model) to be protected from being eaten by predators.

The model runs in a discrete time manner, i.e., each individual does its action in each simulation step, or tick (Fig. 1 A and B). At the beginning of each model run, monarchs and viceroys have different colour and thus are visually distinguishable to birds. During model runs, the three species, birds, monarchs and viceroys fly randomly in a two-dimensional world. Monarchs and viceroys are preyed by birds when they encounter. When a bird eats a monarch, it memorizes the monarch's colour as "yucky" and avoid capturing preys in the same colour in the next several steps until its memory decays to null. A bird can remember up to three yucky colours and the previously memorized yucky colour is replaced by the newly tested yucky colour. Monarchs and viceroys regenerate through asexual reproduction to compensate the loss of population. The chance of reproduction depends on their population size. The closer their population size to the carrying capacity that is 225 individuals for each prey species, the lower the chance to reproduce. In addition, a simply random test (4%) is applied before the reproduction can be made. Once a monarch or viceroy is reproducing, the offspring is either an identical copy of the parent or having a mutation rate to be a mutant which is the same species as the parent but has a random colour between the model and mimic species (i.e., from 15 to 105). Both monarchs and viceroys have equal chance to produce a mutant.

The model has three critical parameters to be manipulated in this research to test our hypotheses. Memory duration defines the time interval that a bird can memorize a yucky colour in relation to its experience of eating a monarch. The larger the memory retention, the longer the time in which the bird avoids capturing preys of memorized yucky colour. Mutation rate controls the probability of generating a mutant offspring. No mutation means no colour overlapping between model and mimic species, thus all preys are identifiable by birds. High

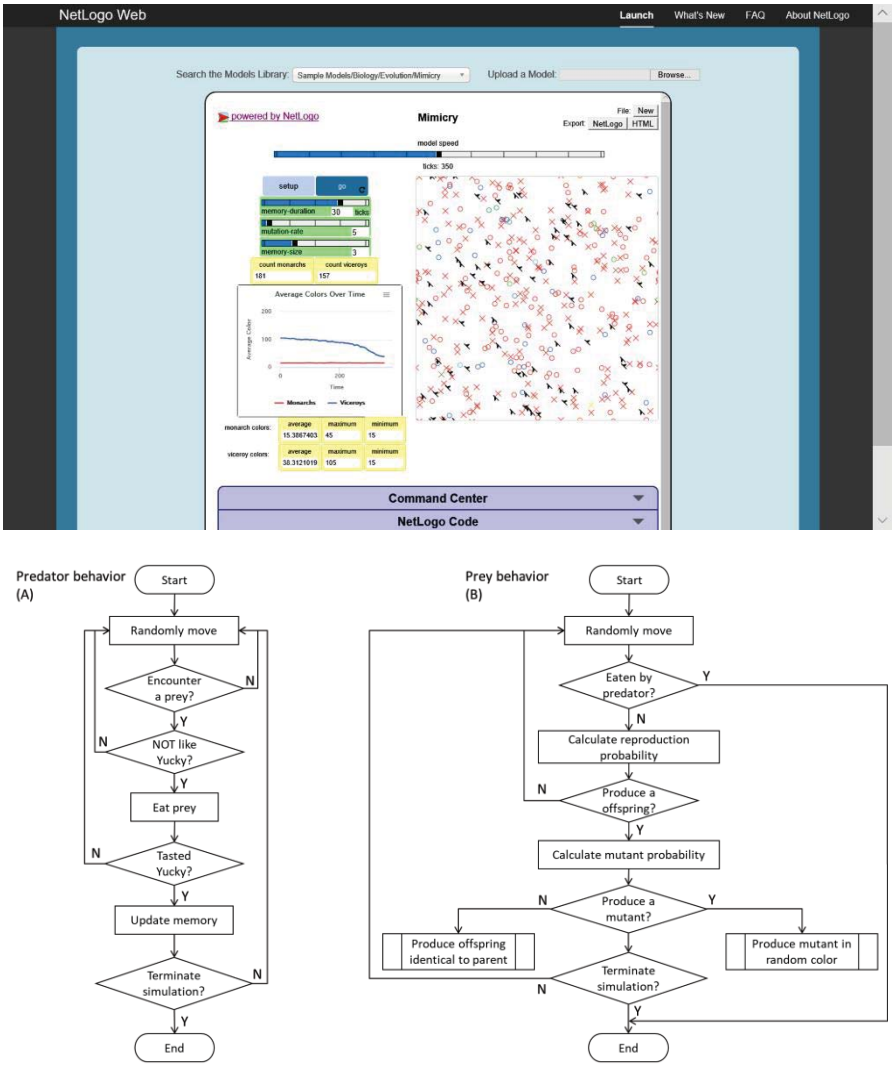


Fig. 1 Screen shot of the NetLogo mimicry simulation model and behavior of predator (A) and prey (B) individuals.

mutation rate leads to confusion of prey identification, but the flip side is that it introduces too much yucky colours to be memorized on the other hand. Thus, there still are considerable number of viceroys could be eaten, which means the efficiency of protection due to mimicry would be discounted. The proper combination of memory duration and mutation rate is vital to achieve Batesian mimicry in the three-species predator-prey system. In addition, there are two environmental relevant parameters, the timing of predator removal event and the frequency of each removal. The manipulation of the two parameters models the situation in which the predator-prey system is disturbed by the removal of a certain number of predators at a specific time point.

3 Simulation experiments

Before we conducted the simulation experiments that are environmental disturbance relevant, we did some pilot simulations based on the predator-prey model to thoroughly explore how the two factors, i.e., memory duration and mutation rate, affect the mimicry between the two prey species. In these pilot simulations, we increased the preys' mutation rate and predators' memory duration gradually from 0.0 to 1.0 and from 0 to 40, respectively. Since the two factors represent traits of the different species that are respectively the prey and the predator

Table 1 Model parameters.

Model parameters	Description	Value	Symbol
Monarch	Initial population of monarch	$0 < m \leqslant 225$	M
Viceroy	Initial population of viceroy	$0 < v \leqslant 225$	V
Bird	Initial population of bird	75	Bird
Mutation rate	Mutation rate of monarch and viceroy	0.01≤M≤1.00	Mutation
Memory duration	The period of time that a bird can remember a yucky colour	1≤T≤40	Memory
Memory size	The number of colours a bird can remember	3 (Constant)	Size
Colour_M	Initial colour of a monarch individual	15≤c_m≤105	c_m
Colour_V	Initial colour of a viceroy individual	15≤c_v≤105	c_v
Model	Type of environmental disturbance	A/B/C/D/E	model

species, we assumed that the two factors are independent to each other. Therefore, when the one factor was increasing, the other was kept as constant. From these pilot simulation experiments, we could clarify in which situation the indirect interactions (mimicry) are important to protect the Viceroy, and to find when the system would go stable by observing the time series charts.

In order to simulate the effects of environmental disturbance that causes predator loss, we removed a certain number of birds from the predator-prey system during simulation. Since the environmental disturbance could vary in both magnitude and time, the different types of removal events were applied during simulation. We defined the types of removal as rapid removal and gradual removal. In rapid removal, the number of birds was cut down from 75 to 10 at one time, i.e., 65 birds disappeared suddenly. However, in gradual removal, the 65 birds were separately removed in 5 batches with a time interval of 200 ticks, in each of which only one-fifth of (13) birds were removed from the system. The timing of removal was defined as the time point when the removal events occurred. We assumed that there might be various direct and indirect interactions among predator and prey populations when the predator-prey system evolves, therefore the disturbance that occurred before and after those interactions becoming well situated could have different impact on the system dynamics. We let the removal events occurring at the time point of 200 and 1000 respectively, to model disturbance striking the unstable and stable predator-prey system. We therefore defined the disturbance combination of removal timing and type as five models, i.e., model A, B, C, D and E (Table 2), where no disturbance was applied in model A that can be regarded as a control for comparison purpose.

To investigate the effects of mimicry, i.e., the indirect interactions among prey species, on the disturbance of predator loss, we changed the value of mutation rate of the two prey species and the memory duration of birds for all the five models. According to the value range defined in the predator-prey model, we used three levels for the two factors, i.e., low, intermediate (mid) and high mutation rate and memory duration. For mutation rate, the value of the three levels were 0.2, 0.4 and 0.8; for memory duration, the value of the three levels were 8, 16 and 32 ticks of simulation steps.

Then, we designed the total 45 simulation experiments for the combination of all interested conditions in a full factorial manner, as shown in Table 2. Each simulation experiment ran 2000 ticks before ending. In order to eliminate the effects of randomness, we replicated each simulation experiment for 100 times. In each simulation experiment, we collected colour of each prey individual and the population changes over time of each prey species for analysis.

Table 2 Parameters for simulation experiments.

Experiment	Model	Timing of predator removal	Type of predator removal	Mutation rate	Memory duration
1	A	N/A	N/A	Low	Low
2	A	N/A	N/A	Low	Mid
3	A	N/A	N/A	Low	High
4	A	N/A	N/A	Mid	Low
5	A	N/A	N/A	Mid	Mid
6	A	N/A	N/A	Mid	High
7	A	N/A	N/A	High	Low
8	A	N/A	N/A	High	Mid
9	A	N/A	N/A	High	High
10	B	200 (Before stable)	Rapid removal	Low	Low
11	B	200 (Before stable)	Rapid removal	Low	Mid
12	B	200 (Before stable)	Rapid removal	Low	High
13	B	200 (Before stable)	Rapid removal	Mid	Low
14	B	200 (Before stable)	Rapid removal	Mid	Mid
15	B	200 (Before stable)	Rapid removal	Mid	High
16	B	200 (Before stable)	Rapid removal	High	Low
17	B	200 (Before stable)	Rapid removal	High	Mid
18	B	200 (Before stable)	Rapid removal	High	High
19	C	1000 (After stable)	Rapid removal	Low	Low
20	C	1000 (After stable)	Rapid removal	Low	Mid
21	C	1000 (After stable)	Rapid removal	Low	High
22	C	1000 (After stable)	Rapid removal	Mid	Low
23	C	1000 (After stable)	Rapid removal	Mid	Mid
24	C	1000 (After stable)	Rapid removal	Mid	High
25	C	1000 (After stable)	Rapid removal	High	Low
26	C	1000 (After stable)	Rapid removal	High	Mid
27	C	1000 (After stable)	Rapid removal	High	High
28	D	200 (Before stable)	Gradual removal	Low	Low
29	D	200 (Before stable)	Gradual removal	Low	Mid
30	D	200 (Before stable)	Gradual removal	Low	High
31	D	200 (Before stable)	Gradual removal	Mid	Low
32	D	200 (Before stable)	Gradual removal	Mid	Mid
33	D	200 (Before stable)	Gradual removal	Mid	High
34	D	200 (Before stable)	Gradual removal	High	Low
35	D	200 (Before stable)	Gradual removal	High	Mid
36	D	200 (Before stable)	Gradual removal	High	High
37	E	1000 (After stable)	Gradual removal	Low	Low
38	E	1000 (After stable)	Gradual removal	Low	Mid
39	E	1000 (After stable)	Gradual removal	Low	High
40	E	1000 (After stable)	Gradual removal	Mid	Low
41	E	1000 (After stable)	Gradual removal	Mid	Mid
42	E	1000 (After stable)	Gradual removal	Mid	High
43	E	1000 (After stable)	Gradual removal	High	Low
44	E	1000 (After stable)	Gradual removal	High	Mid
45	E	1000 (After stable)	Gradual removal	High	High

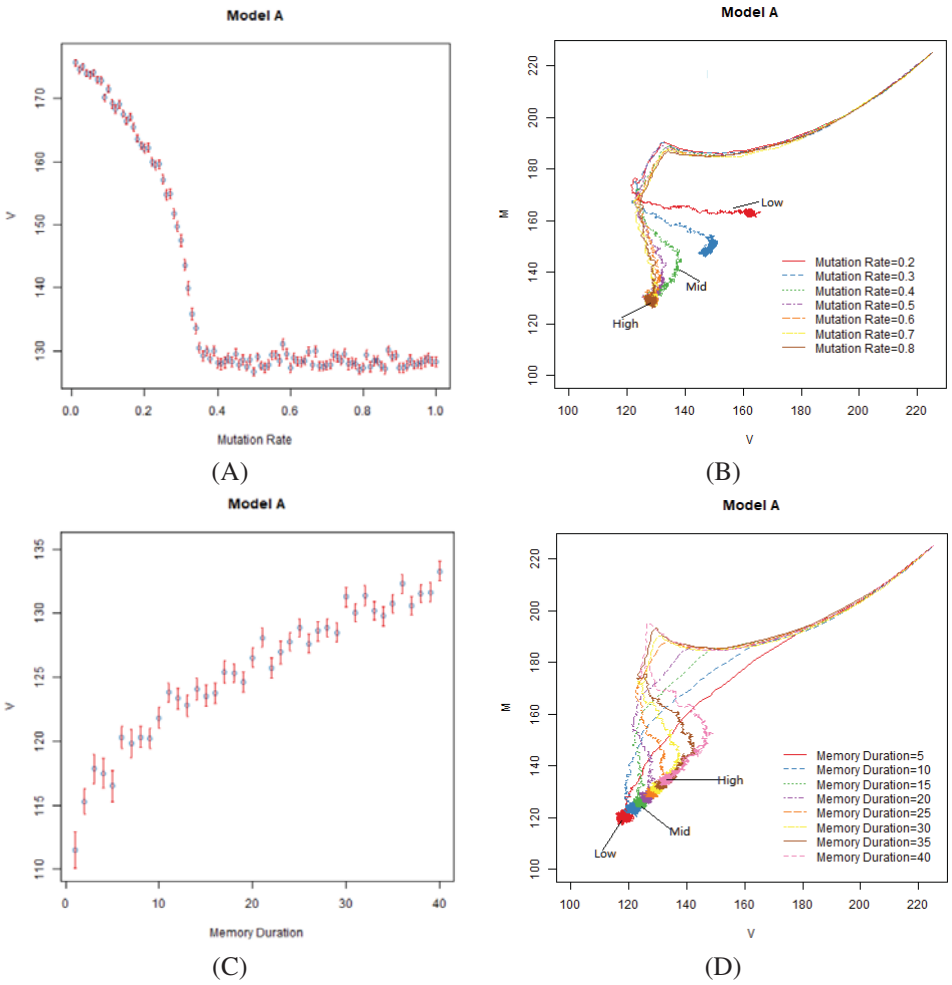


Fig. 2 Viceroys population changes when different mutation rate (A) and memory duration (C) were applied. Phase diagrams of population dynamics of monarch vs viceroy under different mutation rates (B) and memory durations (D). Error bars represent standard errors.

4 Results

4.1 The effects of preys' mutation rate and predators' memory duration on mimicry

Batesian mimicry enhances the protection of imitating species (i.e., viceroy species, the mimic) through the indirect interactions with the imitated species (i.e., monarch species, the model). The population size of viceroy is therefore naturally selected as the indicator of mimicry strength between the two preys. In other words, the more viceroys in the system, the stronger the mimicry protection. Simulation results showed that higher mutation rate leads smaller viceroy population size, but the trend stop continuing after the mutation rate approximately beyond 0.4. Lower mutation rate, e.g., between 0.1 and 0.2, can sustain the largest number of viceroys (Figure 2A). The phase diagram also showed that the increment of mutation rate causes a nonlinear declination of mimicry strength (Figure 2B). However, the elongation of memory monotonically increased the mimicry strength. The explanation is quite straightforward. Since predators only memorize negative experience, the longer the yucky colours have been held in their memory, the more avoidance of capturing preys that have the memorized yucky colours will be. This therefore increased the survival probability of the viceroy species.

The effects of mutation rate on mimicry can be explained by looking into how offspring colour changes with the variations of preys' mutation rate (Figure 3). At the beginning of simulation, monarch and viceroy were

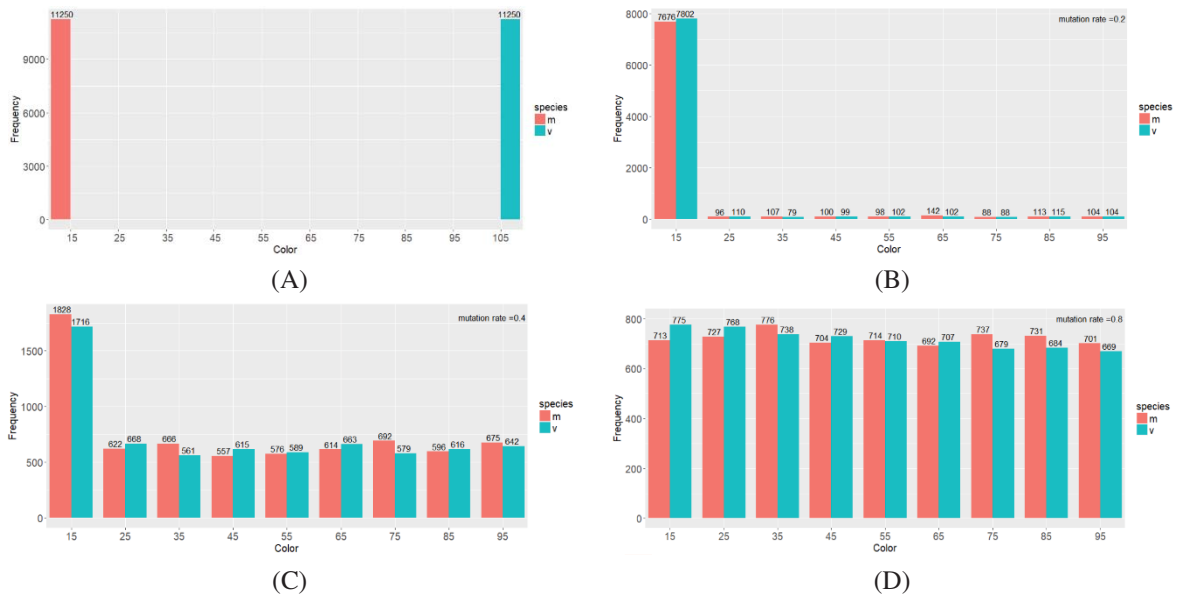


Fig. 3 Color distribution of the two prey species population, monarchs and viceroys at the beginning of the simulations (A) and comparisons at the end of simulations between different mutation rates that were 0.2 (B), 0.4 (C) and 0.8 (D) respectively.

completely visual distinguishable by their colours which were respectively 15 and 105 (Figure 3A). However, at the end of simulation, varying in mutation rate changed the colour distribution of the preys. In general, viceroys are more likely to be eaten by birds due to being palatable, which means that their population is replaced by their offspring more quickly than monarchs. This is the reason why we can observe that lower mutation rate maintained the large population of monarch offspring of red colour (15), but most of the viceroy population evolved from their ancestors' blue colour (105) to red colour (15, Figure 3B) to gain more protection. In this situation, most viceroys shared the same colour with monarchs to achieve the strongest mimicry strength. As mutation rate went high, the number of monarchs that remained the colour of 15 became less and less because they reproduced more mutants that are randomly coloured from 15 to 105 (Figure 3C and 3D). The mimicry favourable situation where large population of prey aggregated in the same colour became rare and rare, then the number of viceroys protected by monarchs decreased. One should note that in this model, the number of yucky colour that a bird can memorize was limited to 3, which is applied in most predator-prey system. This explained the situation in Figure 3D where more paired monarchs and viceroys were in the same colour but sustained less viceroys than the situation where mutation rate was low.

4.2 The effects of timing and type of predator removal on flourishing prey population

Surprisingly, gradual removal did not make a difference in the final viceroy population compared with rapid removal, i.e., the frequency of removal did not change the system behaviour. Comparisons between model B and D, where part of predator was removed rapidly and gradually, showed that viceroy population eventually went back to the same level no matter how much the mutation rate was applied (Figure 4A and 4C) except for the situation where mutation rate was 0.4. The same held for model C and E (Figure 4B and 4D). This consistency remained in both situations where removal was made before stable and after stable (Figure 5A and 5D). This can be explained by that the three-species predator-prey system is a linear system in some cases. It is suggested that the number of viceroys sustained by the system through the indirect interactions (mimicry) with monarchs is approximately a linear relationship with the number of predators. Therefore, once a proportion of predators was swept out from the system, a certain number of viceroys added to the system no matter how the predators were removed. This system behaviour can be observed from the phase diagram in Figure 4, where the trajectories of

monarch and viceroy population stabilized on the diagonal line.

The most interesting finding was that the timing of predator removal did make a difference in viceroys' population growth (ANOVA, df=198, F=7.433, $p<0.001$, Figure 6A and 6B). But this only occurred in the situation where mutation rate was intermediate (0.4) and memory duration was high (32), as shown in Figure 5B and 5E. When predator removal was done at tick 200 where the viceroy population was still going up, the average of viceroy population went to 208 in BOTH model B and D. However, when predator removal was done at tick 1000 where the viceroy population was close to the stable state, the average of viceroy population went to 203 in BOTH model C and E.

This finding can be explained by looking into the evolution process where viceroys varied their colours and sought for protection. At the beginning of simulation, most viceroys were in blue colour which was easily identified by bird, thus their population went down quickly. When some viceroys produced mutants that were in red colour and naturally protected by monarchs of the same colour, the mutant population started to growth because they had higher probability to generate red offspring. In this way, the population of viceroy mutants was overgrowth and reached a level that beyond the mimicry protection. Because the viceroy density became higher, birds had higher chance to encounter a palatable and red viceroy, which obviously destructed the memory of yucky experience contributed to mimicry. Then the population of viceroy mutants started to go down, as shown in ticks between 0 and 500 in Figure 5. If some birds were removed from this system at the stage when viceroy mutants were overgrowth, these extra number of viceroy mutants were kept in the system because parts of their natural enemies no longer existed. On the contrary, if some birds were removed from this system when viceroy population was close to stable, i.e., the population was balanced between being hunted and protected, thus no extra viceroy mutants were produced. This is the reason to explain why the timing of predator removal made a difference in flourishing mimic population.

However, this difference was only found in a certain situation where the preys' mutation rate was intermediate (0.4) and the predators' memory duration was high (32). As we discussed earlier, the combination of low mutation rate and high memory duration can achieve the strongest mimicry strength that protect viceroy well. But results showed that higher or lower mimicry strength (i.e., the indirect interactions between prey species) did not make difference in viceroy growth when parts of predators were removed. It suggested that in strong indirect interaction scenario where mutation rate was intermediate and memory duration was high, more viceroys were supported due to the strong mimicry strength. In other words, the balance of viceroy population between being hunted and protected has been well kept all the way during system evolution. This explanation held when mimicry strength was low.

5 Discussion and conclusion

5.1 Why individual-based simulation approach was used to understand the indirect interactions between prey species

In this research, we took advantage of the spatially explicit individual based model to investigate the complex interactions among prey and predator individuals in the context where environmental disturbances are considered. In this three-species predator prey system, interactions not only exist between predators and preys where predation and learning occur directly but also are shown between preys in an indirect way as Batesian mimicry (Bates, 1861). To analyse these complex interactions and predict what the role they play in the system subject to environmental disturbance, we need to zoom down into the individual level to model variabilities in space, behaviour and learning rather than population level (Qu et al., 2013). Although differential equation based Lotka-Volterra models are classical and typical tools to study predator prey system and its dynamics (Llibre and Valls, 2007), they are difficult to specify individual level traits such as perception, memory and learning ability which are natural elements forming complex indirect interactions between individuals, species and populations. To the best of our knowledge, no Lotka-Volterra models with inbuilt mimicry evolution have been found. By linking

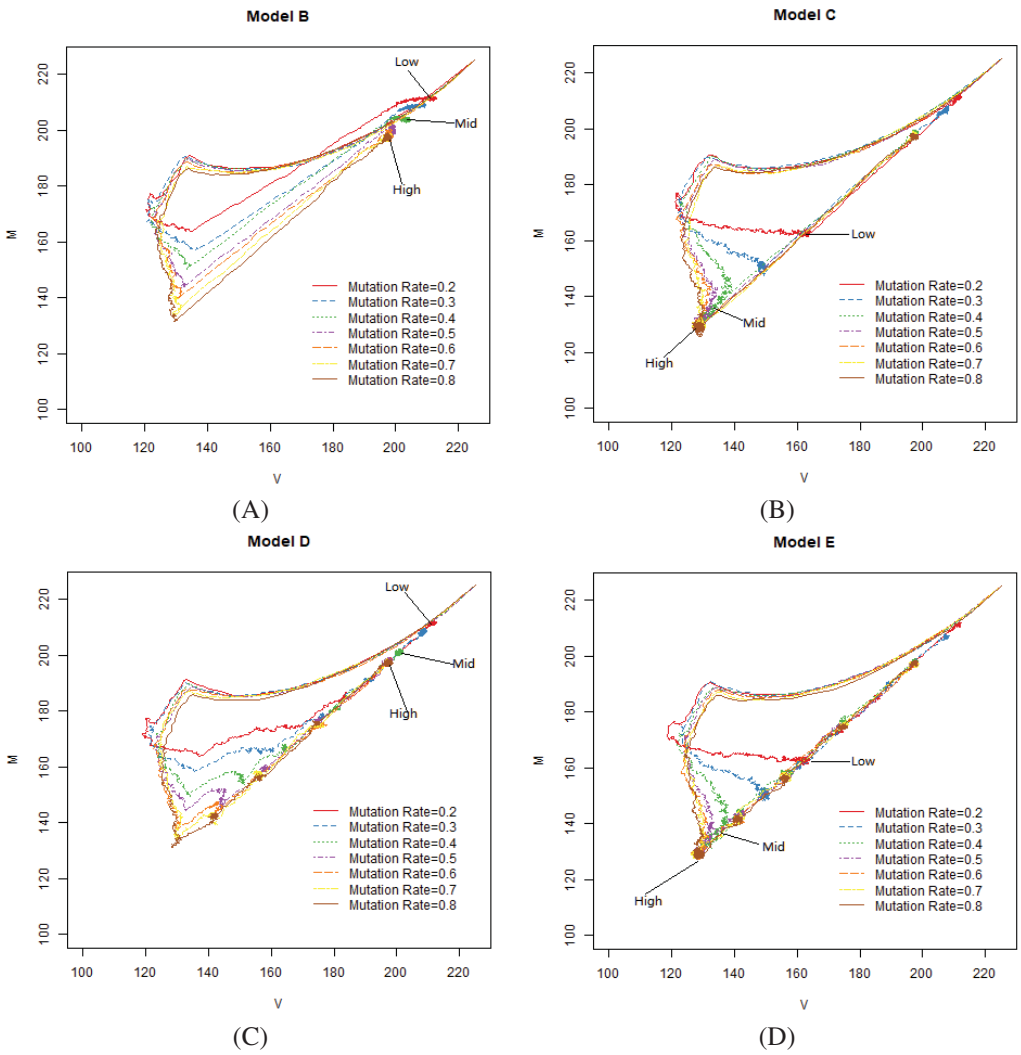


Fig. 4 Trajectories of the monarch and viceroy population with mutation rate from 0.2 to 0.8 of the four model B, C, D and E where memory durations were all set as high (32).

Batesian mimicry into predator-prey system, we were able to reveal how individual behaviours can indirectly affect system evolution and dynamics in facing environmental threats.

5.2 Why indirect interactions are important in facing the environmental disturbance

Environmental disturbance is a major threat to ecosystems and generally reshape their functions by changing species composition (McDonald et al., 2016). A typical disturbance is species disappearing and even extinction, which poses pressures to other species that they are directly or indirectly interact with. Direct interactions such as predations, are usually obvious and not difficult to observe. However, indirect interactions such as exploitation competition and defence which are mediated by third species, are not very easy to observe and quantify (Dunn, 2010). In the three-species predator prey system, preys are expected to increase due to the loss of predators that are killed by disturbance, but their population change may vary due to the indirect interactions occurred between the model and mimic preys. We have observed significant difference in prey population growth when the timing of predator removal changed during mimicry evolution.

This is the first report that addresses the question, which is how indirect interactions such as mimicry affects species abundance when environmental disturbance occurred. In this system, the population of viceroy, one

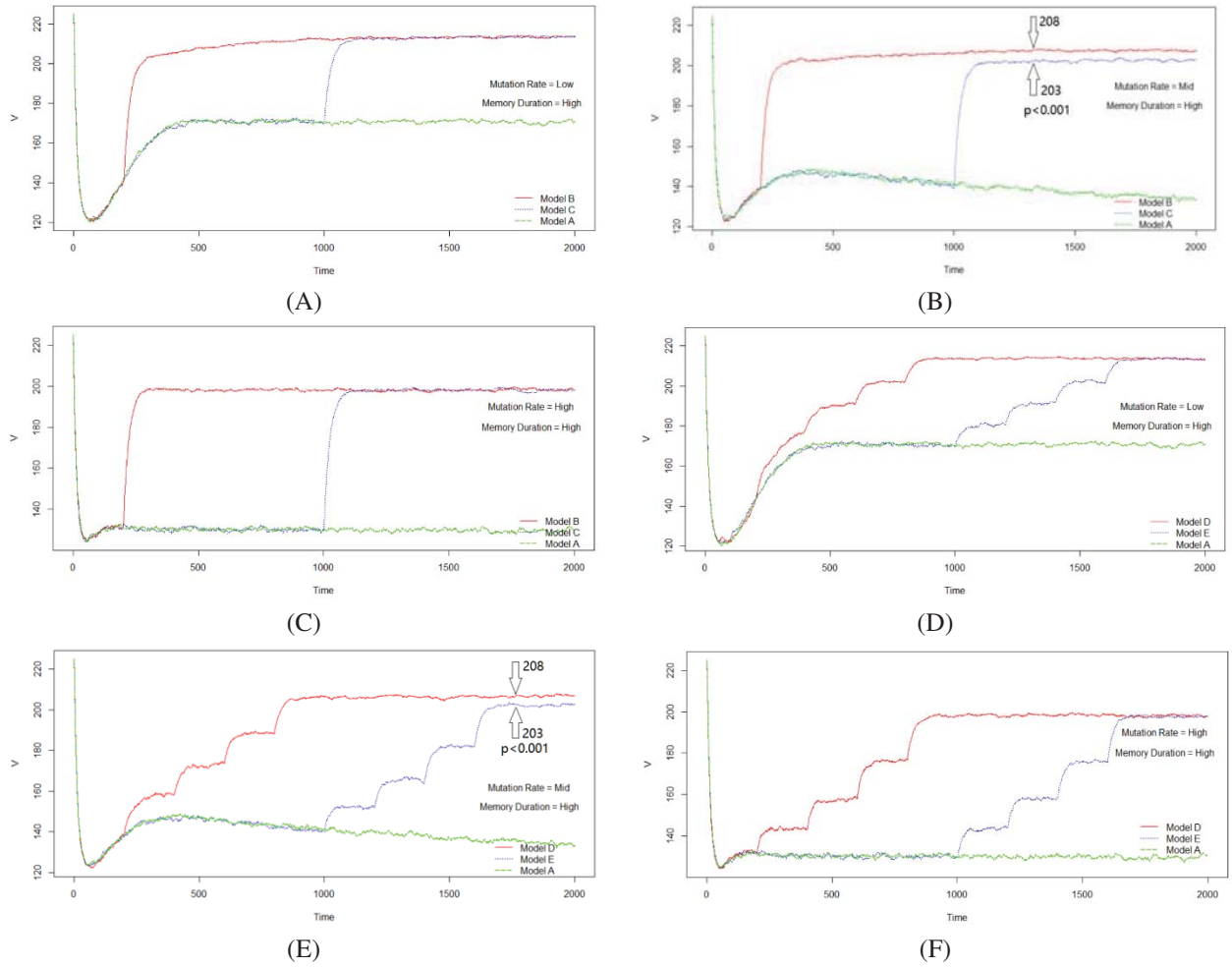
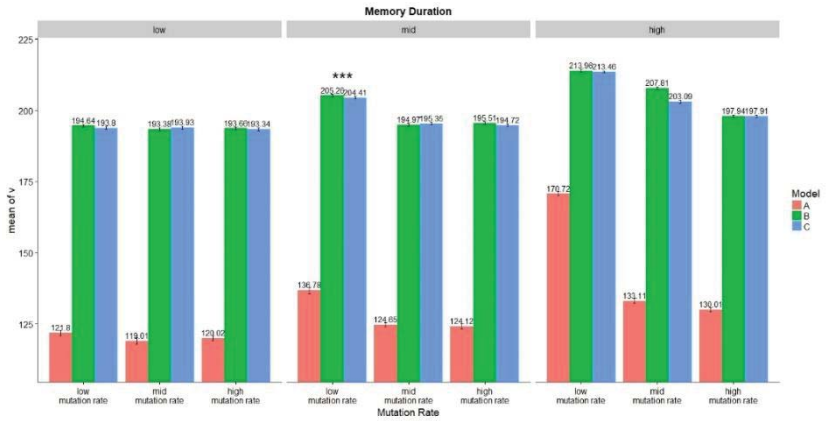


Fig. 5 Time series chart of viceroy population dynamics of model A, B, C, D, E and F with different combination of mutation rate and memory duration.

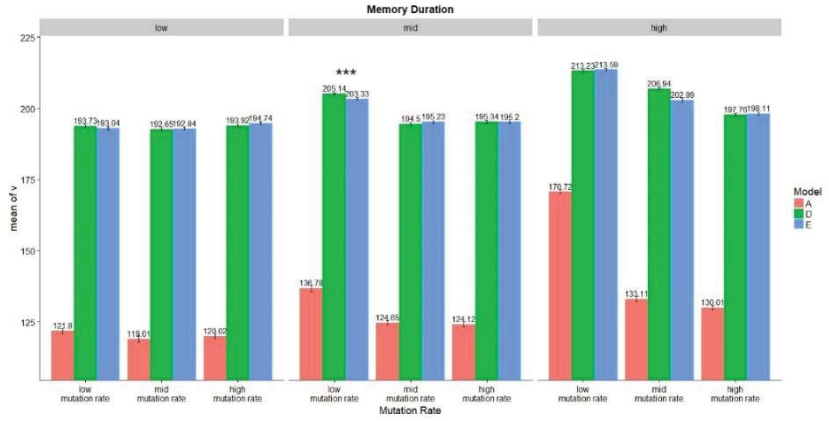
of the two preys, is not only a function of predator abundance but also affected by the abundance of another prey species, the monarch. Viceroys tend to evolve towards the colour of monarchs to increase their survival probability. Viceroy mutants are protected by monarchs but there is a hidden balance in which the sustainable abundance of viceroy mutant must be associated with a certain number of monarchs acting as the source of yucky experience of predator birds. If the viceroy mutants are overgrowth, the excess part is destructive power to weaken mimicry. Because the more viceroys, the higher chance a bird can encounter a palatable viceroy, thus forgets the yucky experience over time. If monarchs provide more protection than the relative small population of viceroy, viceroys tend to increase to reach that balance. The system evolves towards such hidden balance but can be disturbed by environmental changes such as the loss of predators. Our findings suggested that this indirect interaction is able to change the final species composition on the long term evolutionary scale if environmental disturbances occurs in the particular time window.

5.3 What are the implications of the simulation findings to ecological conservation

Interactions and their consequences in the context of environmental disturbance are of special concern in ecological conservation since the environmental conditions have been changed so quickly in the past decades (Stephen et al., 2004). The concept of Batesian mimicry fits into our three-species predator prey system because it can help investigating and explaining how and why these indirect interactions change species composition in a long



(A)



(B)

Fig. 6 Viceroy population (mean of the number of viceroy individuals) comparisons between model B and C (A) as well as comparisons between model D and E (B) when different combinations of mutation rate and memory duration were applied. Difference between model B and C, model D and E in intermediate mutation rate and high memory duration were statistically tested by ANOVA, df=198, F=7.433, $p<0.001$ (marked as ***).

term scale. Our simulation findings suggested that species can be affected not only by direct predation, but also indirect interactions mediated by the third species, which are very common in the food web (Johnstone, 2002). In addition, the timing of environmental disturbance occurred is also critical in reshaping system feedbacks and functions on the evolutionary time scale. This research extended the basic predator prey model and incorporated into complex relations between prey species, which could possibly shed the light on conditions under which species and ecological balance can be better managed when environmental disturbances are inevitable to come.

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Emergy-Based Provincial Sustainability Dynamic Comparison in China

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Abstract

In this paper, we account the emergy of 29 provinces in China in 2012 (excluding Tibet, Taiwan, Hong Kong, and Macao due to lack of data) based on the application of the NEAD accounting framework at the provincial level. Based on the emergy-related data of 29 provinces in 2007, the emergy indicators of 2007 and 2012 are compared and analyzed. This study selected ESR, ED, EIR, and ESI, which can comprehensively represent the indicators of a province's economic, social, environmental, and sustainable development. At the same time, we also use Pearson correlation to analyze the correlation between the four indicators and the three most primitive economic and social indicators (AREA, POPULATION, GDP) to derive the internal driving factors of the province. Comparing the correlation coefficient in two years can lead to changes in the internal driving factors of the province. We draw the following conclusions: (1) From 2007 to 2012, the resources development in the western region is remarkable, and the central and eastern regions have made some efforts on sustainable development on the basis of the better economic development. However, there is still a long way to go before the economic and environmental conflicts are resolved. There is still a lot of effort to reach the level of comprehensive sustainable development. (2) The larger the area, the stronger the sustainable development capability, and from 2007 to 2012, this trend has weakened. The greater the GDP, the weaker the capacity for sustainable development, but from 2007 to 2012, this trend has weakened. There is no obvious correlation between population and economy, society and sustainable development.

1 Introduction

The growing depletion of resources and environmental degradation is stimulating the reflection on alternatives to the still-ongoing process of industrial civilization. Sustainable development and ecological civilization represent

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different and complementary proposals with respect to the present unsustainability of human lifestyles. China's rapid urbanization process and extensive development have a high cost in terms of human and ecosystem health. This prompted the Chinese government to pay attention to the sustainability of economic development. At present, regional sustainable development is not only the core content of China's social and economic construction, but also a hot spot for scholars. Sustainability has gradually shifted from a conceptual to an operational level, supported by a gradual improvement of the sustainable development indicator system at different scales.

In the process of sorting the regional level of sustainability, due to the difference in the selection of indicators, the results presented by rankings are very different, even leading to opposite results, such as in the case of the regional sustainable development evaluation based on the SG-MA-ISPA model (Liu, 2012) and the correlation analysis of regional sustainable development indicators and dimensionality reduction model research (Wang, 2001). To overcome such difficulties, many research scholars have proposed to reinterpret sustainable development from a holistic perspective from a new perspective, that is, from external characterization index evaluation to internal mechanism type evaluation. This reflects the paradigm shift tendency, from an anthropocentric to an eco-centric view in dealing with different environmental issues. For example, William Rees et al. proposed Ecological Footprint (EF) theory, and then his student Wackernagel perfected it, which is a biophysical quantitative assessment of the sustainable use of natural resources (Wackernagel et al., 1999). Urban metabolism theory is also one of them. It is the process of importing matter and energy into cities and products, and the process of outputting waste into an analogy with the metabolism of living organisms (Fang et al., 2009). Because it helps to open the black box of the city and explore its internal metabolic mechanism and energy flow process, research in this area has been paid more and more attention by researchers at home and abroad. In this context, a standardized set of evaluation systems that can assess regional sustainable development from the perspective of internal mechanism theory is in line with the needs of contemporary society (Liu et al., 2013).

This study intends to analyze the structure, intensity, efficiency and impacts of societal metabolism with respect to China's 29 provinces. Moreover, development trends in the last five years are considered to provide reliable policy support for decision makers. In parallel, through the correlation analysis among energy, economic and social indicators, the internal driving force of urban development is inferred to derive potential roadmaps for resources optimization and to promote healthy development alternatives for Chinese regions.

2 Methods

2.1 Emergy accounting

Emergy accounting is a method of energy and, more generally, resources flows analysis (Ulgiati et al., 1995). Emergy, which is an abbreviation of "energy memory" or "embodied energy", was first introduced by the system ecologist Odum in 1980s (Nilsson, 1997; Brown et al., 2004). Emergy is defined as the sum of all inputs of energy, directly or indirectly required by a process to provide a given product. Inputs are expressed through a unified metrological system, i.e. solar-equivalent energy, expressed in units of sej (Scienceman, 1987; Ulgiati et al., 1995; Odum, 1996). Emergy evaluates, from a supply perspective, both non-renewable and renewable resources, as well as services, that a system receives form the environment (Yu, 2016). Emergy accounting also enables to distinguish those flows, which carry negligible energy, but are supported by a huge indirect flow of resources (Brown et al., 2004). The introduction and development of emergy accounting, while considering most of the resources, played a revolutionary role in environmental management and policy making. (Odum, 1996; Hau and Bskshi, 2004; Brown and Ulgiati, 2004).

Emergy analysis provides a powerful and comprehensive tool for the investigation of systems at any scale, even larger than the biosphere (Brown et al., 2004). Moreover, it has two advantages. First, it overcomes the inability of many existing approaches (e.g.: exergy) to adequately consider the contribution of ecological processes to human progress and wealth (Arrow et al., 1995; Daily, 1997; Bakshi, 2002; Holliday et al., 2002). Second, it expresses different kinds of inputs in the same form, usually solar energy equivalents, so that the

different quality of resources can be measured (Sun et al., 2016). Although emergy evaluation has been criticized for implicitly assuming that input resources can substitute for each other (Raugei, 2011), the "quality" feature embodied in the transformity concept (e.g., a joule of fuel is not the same, in environmental cost and functional terms, as a joule of Sun or a joule of electricity) weakens this argument (Geng and Zhang, 2013).

In both China and other Countries, emergy analysis has been widely applied for regional analyses. Ulgiati et al. (1994) used an emergy accounting to evaluate the use of energy, environmental carrying and sustainability in Italy, comparing it with other developed and developing countries. Odum and Brown (1999) introduced in detail the energy values and calculation methods of surface biosphere, atmosphere, ocean circulation, soil, energy conversion rate, etc. in the Handbook of Emergy Analysis. Prior to this, Brown et al. (1993) assessed the environmental damage and possible measures to prevent such incidents from the perspective of emergy analysis on the oil spill in Prince William, Alaska. Brown and Mcclanahan (1996) analyzed the economic development of Thailand and the two proposals for the establishment of the Mekong Dam through an emergy perspective. The calculation showed that the per capita energy value in Thailand was less than that in the United States and other developed countries, while the energy value mainly depended on imports. On the other hand, if the dam were built, the siltation would greatly reduce the net energy production rate. Cohen et al. (2006) used emergy analysis to assess the environmental loss caused by soil erosion in Kenya at multiple scales, and proposed that national sustainability is inseparable with environmental input, such as soil protection, by calculating the ecological losses caused by soil erosion and comparing it with other material flows in the economic system. In recent years, many researches have combined the theory of emergy with other technical means. For example, Mellino et al. (2014) applied emergy analysis to GIS monitoring methods to explore the laws of landscape metabolism from the perspective of space and reflect the unsustainability of development through accounting the loss of surface natural capital, which opened up the prospects for multi-disciplinary applications of emergy. Singh et al. (2016) evaluated droughty maize circulatory systems under various soil restorations using energy budget and energy accounting methods. In aspect of sustainable assessment, Nakajima et al. (2015) used emergy assessment methods to explore the role of sustainable horticultural products for regional sustainable development. Reza et al. (2014) applied emergy-based life cycle assessment to study the sustainability of urban road construction and provided management basis for relevant policy making. Saladini et al. (2018) evaluated how the TES framework based on emergy can shed new light by comparing conventional technological alternatives and ecological alternatives for meeting a particular ecosystem service demand.

In China, researches about emergy originated from the Chinese translation of the emergy theory proposed by Odum in 2001. Thus, in "Emergy Analysis of Ecosystems", the emergy theory, methodology and related applications were introduced to China for the first time. Over the past 20 years, emergy analysis gradually gained the attention of scholars in various fields. The research and application of emergy theory has involved countries and regions, the ecological and economic systems of agriculture, forestry, animal husbandry and fishery, nature reserves, and urban complex ecosystems. Li et al. (2001) calculated the sustainable development index of emergy in China from 1978 to 1998 on the national scale. Scholars in Taiwan, Guangdong, Hainan, Beijing, Macau, Qinghai and Jiangxi also assessed the energy value of their provincial or municipal eco-economic systems and provided scientific advice on decisions about local sustainable development (Huang and Odum, 1991; Li et al., 2006; Sui and Lan, 2001; Liu, 2010; Zhang and Lan, 1998; Li and Liao, 2003; Chen et al., 2018). In addition, scholars have also applied the emergy theory to their research expertise. Ruan (2005) applied the emergy theory to analyze the situation of the regional labor force, and based on this, explored the possibility and orderliness of the regional labor force's mobility. Yang (2007) first established a quantitative research system for dynamic sustainable development of mineral resources in China, using energy analysis to provide advice for China's sustainable use of mineral resources. Based on emergy analysis, Liu et al. (2013) explored the internal metabolic processes in the city and provided a path for solving the problem of the identification of the influencing factors of poor metabolism in cities. Liu et al. (2016) compared the national environmental and economic performances by using energy sustainability indicators, turning the perspective of human-centered environment into the perspective of eco-environmental center. Liu et al. (2018) evaluated the production efficiency and sustainability of

large-scale transportation fuel production via fast pyrolysis and hydroprocessing of corn stover in China using emergy analysis approach to increase the efficiency and sustainability of the hydrogen purchase scenario in NCP.

A complete literature review demonstrates that many studies in China have done a single-year emergy value calculation and emergy value index analysis at the provincial level (Huang and Odum, 1991; Li et al., 2006; Sui and Lan, 1998; Li and Liao, 2003; Yu et al., 2016). However, a single-year index can only explain the development of the provinces and the development gap between the provinces in that year. There are also studies on the comparison of multi-year continuous ecological energy value development in a single province (Liu, 2010; Li et al., 2001), but the comparative analysis of many provinces in China is very rare. There are few years of comparative analysis of emergy values and the comparison can show the problems exposed during the development process and the effectiveness of the policy and measures taken.

2.2 Provincial emergy accounting framework

The NEAD Accounting Framework (National Environmental Accounting Database) was comprehensively presented and published by the University of Florida's Center for Environmental Policy Research in 2009. The database is based on the theory of ecological thermodynamics. It uses emergy value accounting methods to cover all major forms of energy, material and human services in 223 countries and regions around the world, and unifies them into solar equivalents. The unit is solar joules (sej), for comparative analysis. (Sweeney, 2009)

In the NEAD accounting framework, emergy assessments for countries or regions is based on all major inflows and outflows, including internal production processes, based on national boundaries. The energy and material flows of the database statistics include dispersed flows from the environment (such as the sun, wind, rain), concentrated flows from the mining (such as metals, fuels, minerals) and purchased materials and services imported from other countries. After the basic data are collected, they will be converted into energy or weight units by conversion, converted into emergy units by transformity and combined and summarized as relevant indicators.

The framework used in this study is based on the emergy value method supporting the NEAD accounting framework, as well as the improved provincial emergy value map based on Chinese characteristics. In this study, based on the input flow, material energy conversion flow and output flow in the emergy value map, an emergy value calculation table is established to conduct environmental accounting for the eco-economic system with provincial boundaries as system boundaries. The emergy accounting table is the main method for describing the evolution of the system within the framework and accounting for all inputs and outputs under the framework, and is the key to build an emergy accounting framework. Specifically, the framework mainly focuses on the calculation of actual material flow, labor, and energy, and establishes an accounting system in the form of a table. The final step in the analysis of the emergy value is to analyze the calculation results and give policy recommendations. The process is as shown in Fig. 1.

The analysis of emergy value in all provinces requires a large amount of data as the basic support. The basic data types cover all aspects of natural, social and economic systems. They are mainly divided into five categories: 23 renewable resources including solar radiation, geothermal, tidal, wind energy, water resources, waves, etc.; 8 internal conversions of eco-economic systems including agricultural production, forest production, livestock production, fisheries production, water withdrawal, electricity use, etc.; a total of 12 local non-renewable resources, including forestry, fisheries, topsoil loss, and fossil energy mining; a total of 36 import and export currency volume and physical quantity including metal, minerals, food & agricultural products, livestock & meat & fish, plastics & synthetic rubber, chemicals, finished Products, machinery & transportation equipment, other refined goods. The 82 basic data are multiplied by 29 provinces, and the total is 2378 basic data. The reason for selecting only 29 provinces for analysis is the lack of energy balance sheets for Tibet, Taiwan, Macau, and Hong Kong.

The data sources mainly include: 2013 Statistical Yearbook, Water Resources Bulletin of each province, 2013 Provincial Input-Output Table (42 departments, 29 tables), Energy Balance Sheet, National Bureau of Statistics official website data, GIS images, related research literature and an estimate of the inability to obtain

data. The dataset selection criteria are generally referenced to the NEAD framework, and are selected from statistical data covered by most provinces or through relevant literature and publications. In addition, spatial data is processed by GIS inversion and can be used in some data such as updateable streams to fill gaps caused by the inability to obtain statistical data. The physical and monetary data of import and export transactions mainly come from the China Commodity Trade Database of the EPS data platform, and the 98 categories of goods are classified into 9 categories for statistics. Emergy transferred in and out from other provinces is converted by the input-output table and the ratio of the import and export currency to the physical quantity.

2.3 Emergy indicators

Emergy indicators are necessary for the purpose of uncovering the properties and environmental performances of a system. Four indicators are selected in this study to measure the society subsystem, the economic subsystem and environment subsystem in 29 regions for the year of 2012.

Emergy self-support ratio (ESR) is the ration of total used natural resources, including renewable and nonrenewable resources to the total emergy used, (R+N)/U. It reflects the local resource reserves and self-supporting ability. It is the embodiment of resource competition in a certain region.

Emergy density (ED) is the ratio of total used emergy to the total regional area, U/Area, reflecting resource gradient available for economic utilization. It is the embodiment of the overall development of the whole society.

Emergy investment ratio (EIR) is the ratio of emergy fed back from outside the system to the indigenous emergy inputs, IMP/(R+N). It reflects the preference of financial capital for each province and the efficiency of regional benefits in the process of economic development. It is the most representative indicator for measuring the development of regional economic sub-system.

Emergy sustainability index (ESI) is the ratio of EYR to ELR, which reflects the overall sustainable use of natural resources in the studied region. It is the representation for the level of sustainability.

EYR and ELR are two indicators which are involved in ESI. Emergy Yield Ratio (EYR) is the ratio of total used resources to imported resources, U/IMP, reflecting the overall economic efficiency of one system. Environmental loading ratio (ELR) is the ratio of local nonrenewable and imports to local renewable resources, (IMP+N)/(R+R1), reflecting the total environmental impact to one system.

2.4 Pearson correlation

The Pearson Correlation Coefficient is applied to characterize the correlation between the indicators: the two social indicators of the city—area and population and an economic indicator—GDP, to explore the internal drivers of urban development, and to compare 2007. The degree of impact of various factors on urban indicators are compared considering year 2007 and 2012.

The Pearson correlation coefficient describes the closeness of the relationship between the two fixed-play variables, and always measures the correlation (linear correlation) between the two variables. The value is between -1 and 1, generally denoted by r.

$$r_{xy} = \frac{n\sum XY - \sum X \sum Y}{\sqrt{[N\sum X^2 - (\sum X)^2][N\sum Y^2 - (\sum Y)^2]}} \tag{1}$$

where n is the sample size, and X and Y are the observed values of the two variables, respectively.

If $r_{xy} > 0$, it means that the two variables are positively correlated, that is, the larger the value of one variable, the larger the value of the other variable; if $r_{xy} < 0$, it means that the two variables are negatively correlated, that is, the larger the value of one variable, the value of another variable will be smaller. The larger the absolute value of r, the stronger the correlation.

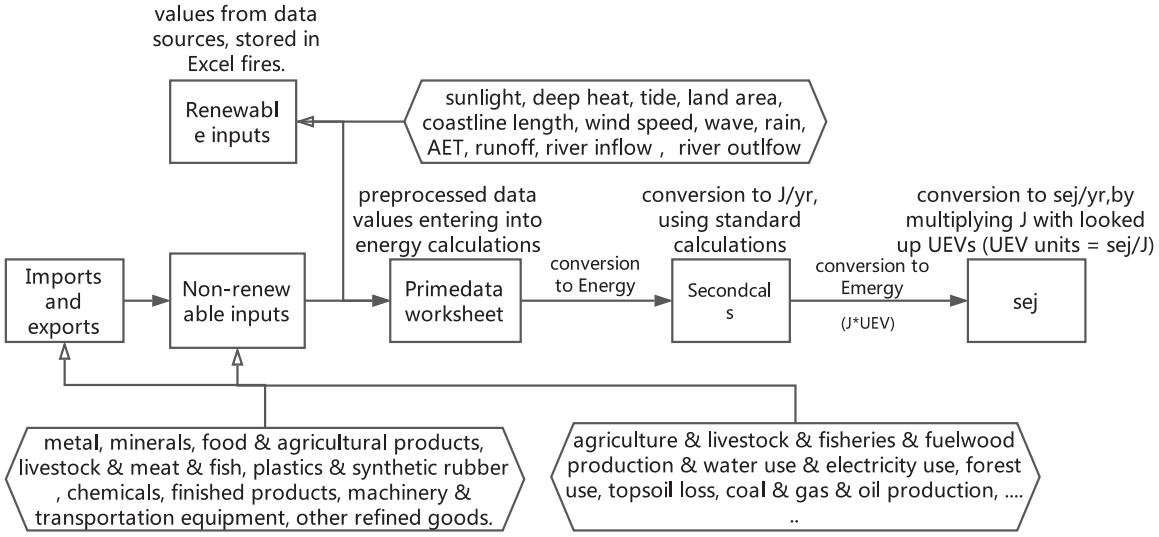

Fig. 1 China's provincial emergy calculation process.

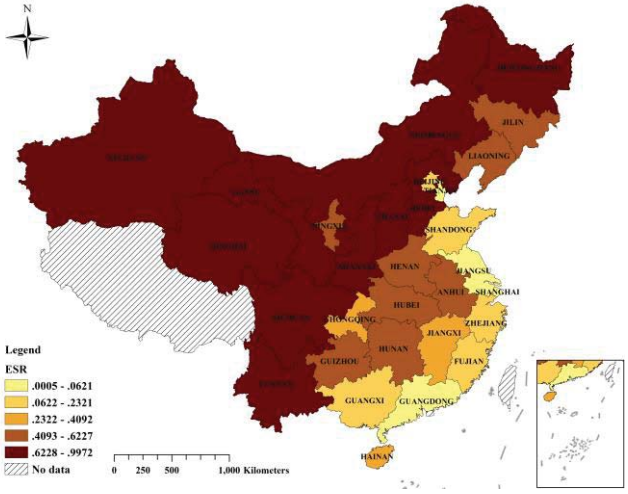

Fig. 2 Spatial disparity map of national provincial ESR in 2007.

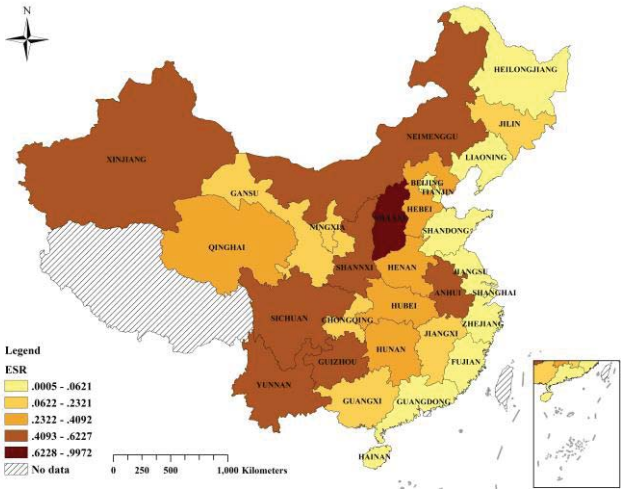

Fig. 3 Spatial disparity map of national provincial ESR in 2012.

3 Results

3.1 Spatial analysis and comparison of China's provincial sustainability in 2007 and 2012

In order to visually reflect the overall situation of sustainable development in all provinces of the Country, GIS mapping is used to carry out provincial-level sustainable spatial differentiation analysis in China. Among them, ESR is emergy value source structural indicator, ED is a social development indicator, EIR is an economic development indicator, and ESI is a sustainable development indicator. These four indicators can fully describe the development of a city, so these four indicators were chosen. The classification criteria for each indicator in 2007 and 2012 are the same, so the change can be judged from the color depth.

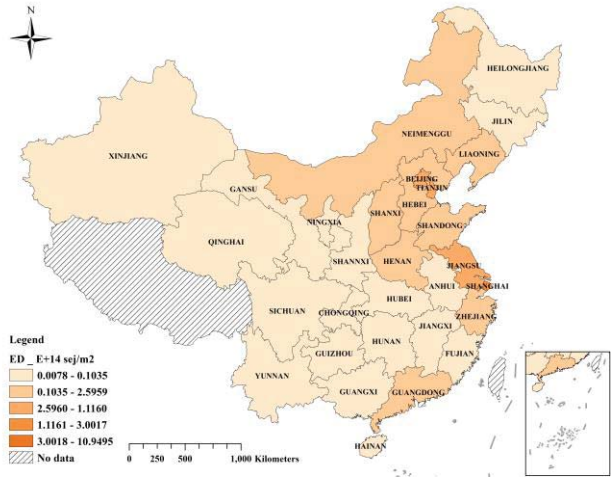

Fig. 4 Spatial disparity map of national provincial ED in 2007.

Fig. 5 Spatial disparity map of national provincial ED in 2012.

3.1.1 Emergy value source structural indicator - emergy self-support ratio (ESR)

The ESR reflecting local resource reserves and self-supporting ability (Figures 2 and 3) is the embodiment of resource competitiveness in a certain region. The deeper the color, the larger the self-sufficiency rate of the energy value, that is, the stronger the resource reserves and self-supporting ability.

It can be seen intuitively from the map that the ESR in the eastern regions with dense economic activities, tight land use and high population density is relatively low, basically below 10%, mainly depending on the transfer of resources from other provinces. In North China, Central China and Southwest China, the ESR is in the middle, as a resource replenishment area in the eastern coastal economic belt, supporting the development of coastal areas. Western regions such as Xinjiang, Inner Mongolia, and Qinghai are rich in natural resources compared to the central and eastern regions. From 2007 to 2012, it can be clearly seen that the self-sufficiency rate of energy value in the western region has declined, indicating that the development of the western region has been strong in the past five years, and the resource reserves and environmental conditions have declined.

3.1.2 Social development indicator – emergy density (ED)

The ED (Figures 4 and 5) reflects the economic development intensity, population intensity and economic development level of a region. The deeper the orange, the larger the ED, that is, the higher the level of social development.

In this study, due to the lack of physical quantities exported from Shanxi to other provinces in 2012, the non-renewable energy data used locally was too large, and the calculation of ED in Shanxi Province also produced large errors, so Shanxi Province was not included in the analysis here. In general, the eastern region, including Shanghai, Beijing, Tianjin, Jiangsu, Zhejiang, Guangdong, Fujian and other regions, as well as Shandong and Hebei in the central region, have high energy use, and the economy is more developed, but at the same time, the environmental load is also large; Most areas of the zone and the northeast belong to the second echelon of energy density. The overall economic development level of these areas is generally at the upper-middle level, and the living standards of residents are guaranteed. The western region belongs to the third echelon of emergy density, in the overall economic development level. At the middle and lower levels, the density of development and the degree of intensification are relatively low. From 2007 to 2012, the level of economic development has not changed much, but from the numerical point of view, the gap between the western region and the central and eastern regions has gradually narrowed, which also shows that the degree of development in the western region is relatively large and has certain effects.

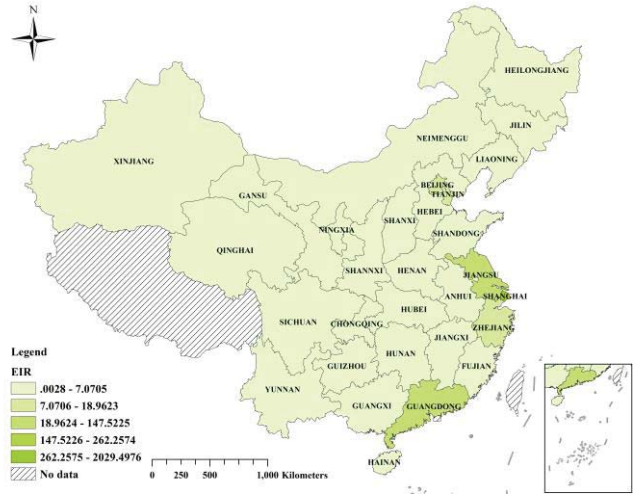

Fig. 6 Spatial disparity map of national provincial EIR in 2007.

Fig. 7 Spatial disparity map of national provincial EIR in 2012.

3.1.3 Economic development indicators - emergy investment ratio (EIR)

The EIR (Figures 6 and 7) reflects the preference of financial capital for each province, and reflects the efficiency of the benefits of various regions in the process of economic development. The deeper the color, the larger the EIR, the more preferred the financial capital, the higher the efficiency.

The nationwide value-added investment is highly concentrated in the eastern coastal provinces and cities such as Shanghai, Beijing, Tianjin, Jiangsu, Zhejiang, and Guangdong. It not only reflects the importance the state attaching to the development of the east, but also reflects the huge economic scale of the coastal development province. From 2007 to 2012, the difference between the central provinces and the western provinces and cities was reduced. From the numerical point of view, the western provinces and cities were slightly lower than the central provinces and cities. On the one hand, it shows that the development potential of western cities has begun to manifest, and it has gradually narrowed the differences with the more developed regions. On the other hand, it has also indicated that the location restrictions in the west have been improved, which partly reflects the effectiveness of the country's western development policy, but at the same time there is still a need to continue to develop resource support and technical input.

3.1.4 Comprehensive assessment of regional sustainable development levels - emergy sustainability index (ESI)

ESI (Figures 8 and 9) reflects the level of sustainable development of the city. The darker the color, the better the level of sustainable development. As can be seen from the figure, the level of sustainable development generally decreases from west to east.

From 2007 to 2012, the overall value of the ESI is on the rise, that is, the overall level of sustainable development is on the rise. However, in view of economic development indicators, the degree of economic development and the level of sustainable development are opposite. This shows that the development of economically developed areas mainly depends on the trend of sacrificing environment and resources. It is hoped that the development of the western region can avoid the development of post-contamination and depletion of resources, and should be improved while protecting natural resources and the environment. The industrial structure develops towards ecological civilization and achieves coordinated development of economic development and resources and environment.

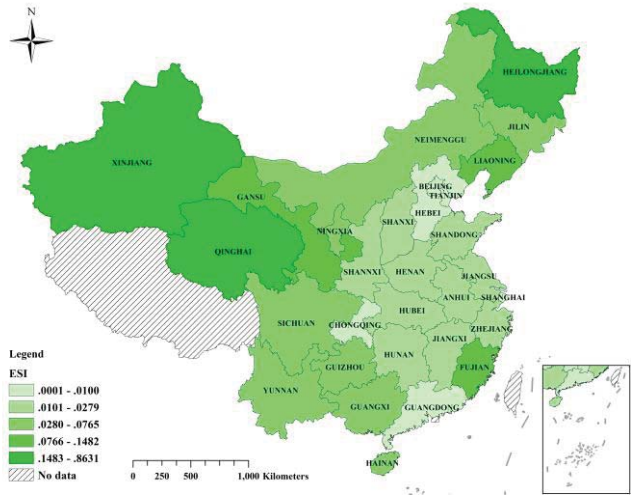

Fig. 8 Spatial disparity map of national provincial ESI in 2007.

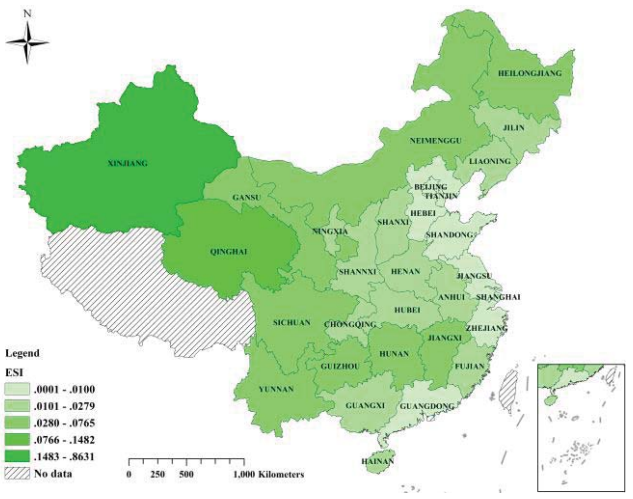

Fig. 9 Spatial disparity map of national provincial ESI in 2012.

Table 1 R values of the Pearson correlation analysis of emergy indicators with AREA, POPULAITON and GDP in 2007.

	ESR	*ED*	*EIR*	*ESI*
AREA	.559**	-.245	-.169	.748**
POP	-.174	-.156	-.135	-.322
GDP	-.531**	.185	.133	-.300

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

3.2 Analysis of the internal driving forces of the provinces and the changes in driving forces in 2007 and 2012

In order to further explore the driving force behind the emergy indicator and explore the changes in the internal driving force of urban development from 2007 to 2012, two social indicators (Area, Population) and one economic indicator (GDP) were selected. Relevant correlations were determined through Pearson correlation analysis (Table 1 and 2).

Below, we report the result analysis from different perspectives. First, AREA and ESI have a positive correlation ($r2007 = 0.748$, $r2012 = 0.931$), and AREA also has a positive correlation with ESR ($r2007 = 0.559$, $r2012 = 0.311$). That is to say, the larger the area, the more resources and the more sustainability. Larger provinces are more likely to get more renewable resources from nature than smaller provinces. From the change of correlation coefficient from 2007 to 2012, it can be seen that the influence of area on the self-sufficiency rate of energy value decreases, that is to say, the area resource reserves with large area begin to decay, indicating the development of large-scale urban natural resources during these five years. Larger.

Second, GDP reflects a country's economy, and GDP has only a strong negative correlation with ESR ($r2007 = -0.531$, $r2012 = -0.322$), and has a weak negative correlation with ESI ($r2007 = -0.300$, $r2012 = -0.228$), almost no correlation with ED and EIR. It is easy to understand that the more developed the economy, the worse the sustainable development and the poorer energy self-sufficiency. From the correlation change from 2007 to 2012, it can be seen that the negative correlation between economic development and sustainable development is obviously weakened, that is to say, the sustainable development of economically developed provinces has improved, and the economy and environment are no longer. There is a strong negative correlation.

Third, the population is often seen as a limiting factor for sustainable development, but in this study the

Table 2 R values of the Pearson correlation analysis of emergy indicators with area, population and GDP in 2012.

	ESR	*ED*	*EIR*	*ESI*
AREA	.311	-.265	-.281	.931**
POP	052	-.206	-.262	-.196
GDP	-.322	.054	.047	-.228

**. Correlation is significant at the 0.01 level (2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

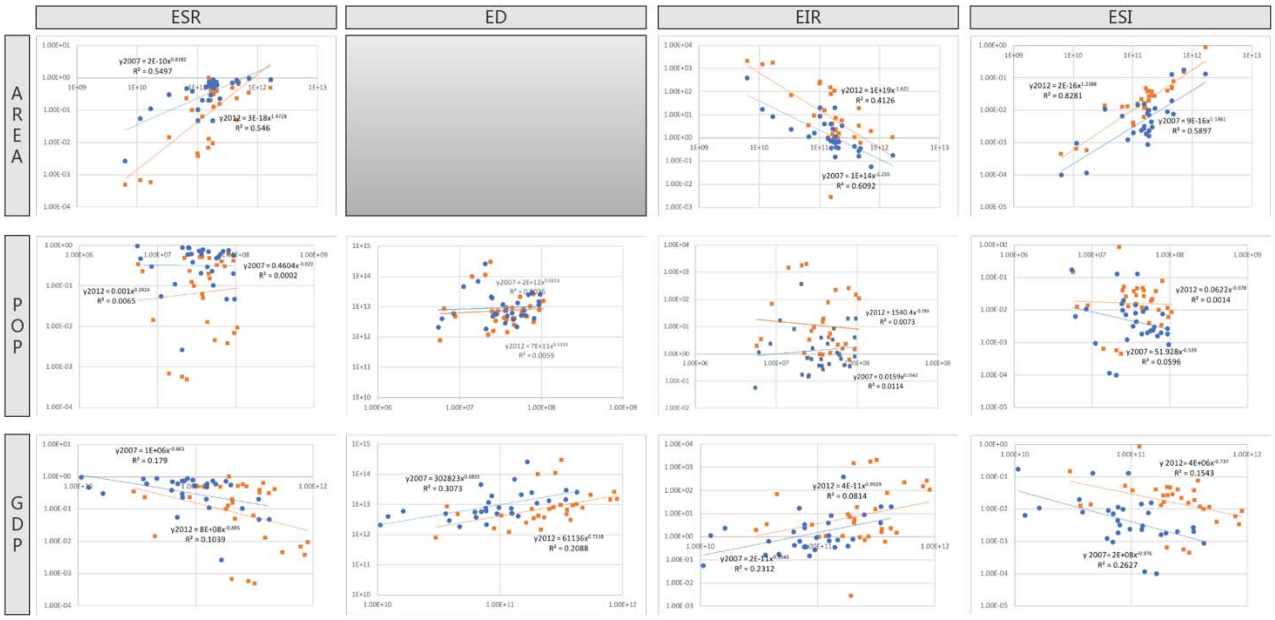

Fig. 10 Scatter plot between emergy indicators and area, population and GDP. Notes: blue dots and lines represents data in 2007, orange dots and lines represents data in 2012.

population has a lower degree of influence, and the population has a less negative correlation with ESI ($r2007 = -0.322$, $r2012 = -0.196$). There is almost no correlation with the other three indicators.

4 Conclusions

In this paper, we use the provincial emergy value accounting framework to perform emergy accounting in 29 provinces of China (excluding Tibet, Taiwan, Hong Kong, and Macau) in 2012. On the basis of energy values data ??in 2007, we selected four indicators that can fully describe the development status of a province, and conducted a two-year comparative analysis to explore the development and development level of the province, and the changing situation within five years. Through the analysis of indicators, we find that the general natural resources in the eastern region are scarce, but the economic and social development conditions are at the optimal level. However, the sustainability is weak, so it urgently needed to be transformed. The natural resources in the central region have not reached the state of complete self-supply. However, it is richer than the eastern region, economic and social development is relatively medium, and the level of sustainable development is medium. The western region is rich in natural resources and can basically reach the level of self-supply. The level of sustainable development is high, but economic and social development is backward. It also needed transformation. Through two years of comparison between the provinces, we found that the rankings of development

in the west, central and eastern regions have not changed much, that is, the level of economic and social development is generally western < central < eastern, and the sustainable development is generally western > central > eastern. However, from the numerical point of view, the economic development in the west has made great progress, while the sustainable development in the east has improved. Moreover, the contradictions between economic and social development and sustainable development have also narrowed, indicating that the measures for the development of extensive economic development in the central and eastern regions have turned into environmental and economic development. At the same time, the western region has carried out large-scale use of its own resources. With the support of the western development policy, the economic development of the technology and talents in the west has improved, but the level of sustainability has declined. It is necessary to pay attention not to take a lot of resources and sacrifice the environment.

At the same time, we also work on the intrinsic driving force of the city, use three economic and social indicators to conduct correlation analysis with emergy indicators, and use Pearson correlation to characterize the relevant situation. We found that the larger the area, the richer the resources and the better the sustainable development. However, such correlations have weakened from 2007 to 2012, indicating that large-scale cities have also carried out large-scale resource development. GDP is negatively correlated with the level of sustainable development, indicating that in 2012 China's sustainable development path of simultaneous economic and environmental development was still far away. The population, which is generally considered to be the limiting factor of development, is considered to have little to do with economic development and sustainable development in this study, indicating that in 2007 and 2012, population restrictions on development were not significant, and gradually decreasing, perhaps we need to re-plan the population control.

In response to the above conclusions, this paper explores the following development strategies:

(1) For the western region, which was rapidly developing with natural resources, it is necessary to focus on sustainable development while maintaining economic strength, and not to develop the economy at the expense of natural resources. Through policy support, increase the construction of infrastructure, ensure a convenient transportation system, and strengthen investment in technology and education. While breaking the constraints of traditional geographical conditions on economic development, we will take a road to sustainable development at no expense of the environment.

(2) For the eastern coastal areas with high economic development and low levels of sustainable development, we must continue to focus on the sustainability of development. Focus on improving the efficiency of resource utilization, introducing and developing green industries, optimizing energy structure, creating a resource-saving society, strengthening the use of renewable resources, reducing dependence on non-renewable resources, and truly implementing policies into action. At the same time, because the correlation between population and economic development and sustainable development was not significant, and the correlation was gradually weakened, it is necessary to re-plan the population control policy.

(3) From the perspective of the national as a whole, deepening inter-regional cooperation between the eastern and western regions has already produced certain effects. It can continue to deepen cooperation and integrate the advantages of capital, talents and technology in the eastern region and the transformation of resources, environment and labor in the inland regions.

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Optimization of the Gram Staining Method Based on Superparamagnetic Magnetic Nanobeads

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Abstract

Gram staining is a widely used method for bacterial identification, where an alcohol burner is used as the fixed step, which requires a high level of proficiency, while the open flame is a potential fire hazard. A rapid, convenient and alternative method is also available that does not require a microscope or alcohol burner. This method utilizes the adsorption capacity of magnetic nanobeads. Ferriferous oxide beads are made by means of the co-precipitation method and adsorb bacteria in suspension liquid after being coated on the surface. The staining process omits the "heat" step and the need for a microscope, and distinguishes bacteria through the observation of the color of the liquid. According to our results, the behavior of this magnetic material performs well with various types of microbes. In particular, the color is clear and is easily distinguishable.

1 Introduction

Gram staining is a widely used staining and identification method in bacteriology. Given that the refractive index of bacteria is similar to the surrounding air, it is nearly impossible to observe bacterial structure under a microscope without staining. Identification can only be achieved after staining. This is because the cytoplasm in its entirety is colored, and the detailed structure of bacteria can be clearly observed with the naked eye. In order to achieve the "fixed" step which immobilizes bacteria on the slide, the traditional the Gram staining method requires an alcohol burner to dry bacteria by heat and a microscope to examine the bacteria, which increases the operational complexity. Microbe concentrations in the flooding liquid on the slide decrease due to the temperature of the flame, which is difficult to control and produces uncertain results. Moreover, the timing used for the fixed step is only determined by the intuition and experience of the operator.

Microbial smear is also randomly made. Therefore, a balanced or uniform pattern formation of dry bacteria on a slide is difficult to achieve. These factors can lead to inaccuracy, which could subsequently influence results. A Japanese study found that coated magnetic nanobeads can adsorb bacteria in water (Akikazu and Takashi, 2012). In addition, a Norwegian study also found that nanoscale polystyrene beads can be used as an alternative method to identify different microbes (Yazdankhah et al., 2001), and this suggests that effective microbial immobilization can be achieved through the utilization of their adsorption onto such nanobeads. Thus,

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an alcohol burner is no longer necessary to achieve the same objective. Sizemore et al. (1990) provided an alternative method to stain bacteria using fluorescence labels; nevertheless, the method still requires the use of a microscope. However, bacteria can be identified without using a microscope through a chemical reaction following the disruption of the cell wall by observing the color of the cytosol released. A comparison between the traditional method and the alternative optimization method is provided in Table 1.

Nanobeads possess unique qualities, such as good affinity, dispersibility and superparamagetism, that are also able to carry organic material after being coated, and are widely used in the biochemical, medical and materials science fields. Conditions of preparation are convenient and the fabrication cost is low, while synthesis can be achieved in a common laboratory. Such self-manufactured nanobeads can be used in situations where the physical condition requirements of beads are low, such as microbial adsorption experiments conducted during student research training exercises. Li et al. (2012) reported that coated nanobeads had a higher adsorption rate compared to non-coated nanobeads; thus, this study attempted to self-manufacture coated nanobeads to confirm their adsorption capacity.

The process optimization of this study used nanobeads as the main body of adsorption and synthesized ferriferous oxide through the co-precipitation (CPT) method in order to preserve nanobeads over time. A dispersing agent was added in case nanobeads reunited. According to the chemical method, nanobeads were coated with silicon (Si) to enlarge their adsorption area. The culture solution was therefore adsorbed and then the nanobeads were stained. Staining conditions were optimized to achieve a more accurate, easy and rapid process of identification.

2 Materials and methods

2.1 Materials

We obtained iron(II) chloride tetrahydrate (FeCl2·4H2O) (analytical reagent (AR) grade) and iron(III) chloride hexahydrate ($FeCl_3{\cdot}6H_2O$) (AR grade) from the XiLong Chemical Engineering Ltd., China; ammonia (NH_3) and ethyl orthosilicate (TEOS) were from the Beijing Chemical Factory (China); anhydrous ethanol (also referred to as absolute ethanol) and tetramethylhydroxide (TMAH) were from the Beijing Tong Guang Fine Chemical Co., China. For the instruments required for this experiment, we used a fourier-transform infrared spectrometer (FTIR) from Thermo Fisher Scientific (USA); a nanoparticle size and zeta potentiometer from Beckman Coulter Inc.; a DJ1C-40 electric stirrer from Longer Pump Co., Ltd; a precise peristaltic pump BT100-2J loaded with a YZ1515X and a Vortex 3000 Oscillator from Wiggens Co.

The experimental bacteria and the dye were manufactured in our laboratory and at the Environmental Microbiology Laboratory of Tsinghua University.

2.2 Methods

Manufactured magnetic beads:

Fe_3O_4 beads were manufactured using the CPT method, where the main chemical equation used is as follows:

$$Fe^{2+}+2Fe^{3+}+8OH^{-}= Fe_3O_4+4H_2O \quad (1)$$

This study applied the knowledge and optimization experience obtained by Zhang (2004) and Li (2012). Following their suggestions, we separately prepared 0.05 mol/L $FeCl_2$and 0.15 mol/L $FeCl_3$ solutions at a 1:1 ratio, which provided 50 mL of each solution that was then stored in a three neck flask at room temperature (25°C) under N_2 protection. The solutions were stirred while NH_3 was added (dropwise) until it reached a pH level of 10. Following this, the solutions were mixed in a water bath at 70°C for 30 min until fully cured Fe_3O_4 particles were obtained. Nanobeads were then rinsed in ionized water to achieve a neutral pH level under an external magnetic field. Magnetic nanobead powder was made following drying.

Table 1 Comparison between the traditional method and the optimized method.

Examination method	Traditional method Microscope	Optimization Method Naked Eye
Difficulty	Requires a long duration and multiple instruments, flame is difficult to control, fading time and skill set affects results, narrow viewing range of microscope.	No difficulty
Staining results	Bacterial gathering behavior affects staining, nonuniform coloring of inner and outer edges	Good uniformity of microbes in liquid
Safety	An alcohol burner can be a fire hazard, microscopes require electricity to operate	No visible risks
Length of progress	The optimization method reduces the operation time by one-third	

Dispersion and coating:

Nanobeads were suspended in water in a conical-shaped bottle (5 mg/mL suspension), which was added with the same mass fraction as the TMAH solution (Lu et al., 2006). Following this, the solution was mixed for 1 h while adding a NH_3 mixture of TEOS, which was prepared at a 2:1 ratio (Ikner et al., 2011). After mixing, the conical bottle was placed into an external magnetic field. Nanobeads were then first rinsed with ethanol and then with ultrapure water. We determined that nanobeads were clean when no visible solids were observed in the waste liquid. The nanobeads were then dried in an oven to generate powder.

Bacterial Cultivation:

An inoculation loop was used to transfer the original bacterial culture solution by streaking the culture dish plate. Following this, the dish was placed into a thermostatic laboratory incubator at 37°C for 24 h for cultivation. A single colony was selected and transferred to a 50 mL centrifuge tube in a lysogeny broth (LB) medium (5 mL), and the tube was then placed in a incubator set at a temperature of 37°C, at 180 RPM, for 18 h. The bacterial suspension stage was then assumed complete.

Staining and identification:

We weighed out 2 mg of Fe_3O_4/SiO_2 magnetic beads into a 5 mL centrifugal tube, and then added 1.2 mL of the bacterial cultivation solution and fully washed the solution after the shaking procedure was complete. Following this, we added 100 μL of crystal violet and stained beads in the dye solution on a rotary instrument for 60 s, after which we washed the nanobeads in ultrapure water three separative times before adding 100 μL iodide fluid and repeating the procedure, namely, staining nanobeads in the dye solution on a rotary instrument for 30 s before washing in ultrapure water three separate times. The next step was to add a 100 μL 95% ethanol solution, which was oscillated and decolonized on a rotary instrument for approximately 20 to 25 s before washing to the colorless stage. Following this, we diluted the safranin solution to a one-quarter concentration of the original solution and added 100 μL before shaking the dye for 30 s and washing it to nearly colorless. Finally, we added 2 mL of anhydrous ethanol (absolute ethanol) and oscillated the solution to observe whether we could determine the presence of dark purple coloring in the clear liquid that indicated the presence of Gram positive bacterium. Red or pink coloring indicated the presence of Gram negative bacterium, while no color indicated no bacterium.

3 Experimental results

The diameter of magnetic beads is an important physical index by which its properties can be determined. When the magnetic beads are prepared by means of CPT, any small changes in reaction parameters can significantly affect the bead diameter; thus, it is important to determine a suitable set of reaction conditions. Using the knowledge obtained by a previous study (Ikner et al., 2011), changes in conditions, such as concentrations of Fe^{2+}/Fe^{3+} ion ratios, NH_3 and dispersants, will result in different particle sizes.

Fe^{2+}/Fe^{3+} ion ratio concentration effect:

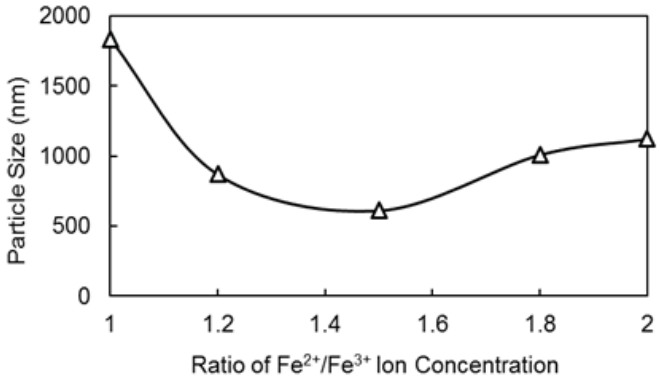

Fig. 1 Effects of the Fe^{2+}/Fe^{3+} ratio concentration on particle size.

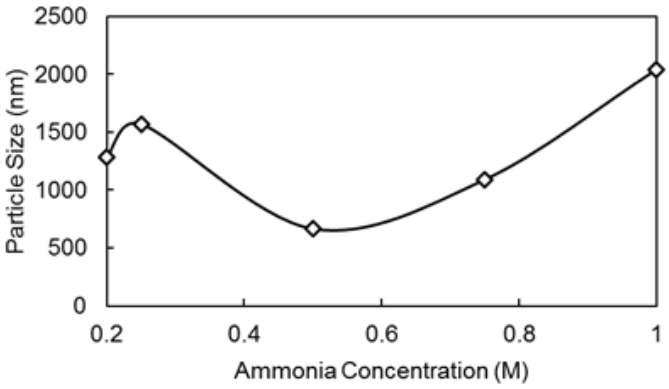

Fig. 2 Effects of the ammonia concentration on particle size.

In this study, the stoichiometric ratio of the equation was set at the upper limit. Given that some Fe^{2+} is oxidized in the air, the lower limit of Fe^{2+} is the same as Fe^{3+}. We gradually increased Fe^{3+} input ratios, namely, 1:1, 1.2:1, 1.5:1, 1.8:1 and 2:1, and then examined the particle size of magnetic beads for all five ratios under the same experimental conditions (see Fig. 1).

Ammonia concentration effect:

The NH_3 concentration determined the instantaneous rate of the OH^- concentration in the solution, namely, a high concentration results in the formation of ferric hydroxide ($Fe(OH)_3$) precipitation, while a low concentration prolongs the reaction time, increasing the possibility of Fe^{2+} oxide and NH_3 metamorphism, subsequently influencing the magnetism of the nanobeads. In our experiment, we selected 0.2, 0.25, 0.5, 0.75 and 1 mol/L to observe the effect of changing NH_3 concentrations on the particles of the magnetic nanobeads (see Fig. 2).

Dispersant concentration effect:

Without a dispersant, our self-manufactured magnetic nanobeads would be difficult to disperse and, therefore, would be prone to agglomerate, subsequently increasing the particle size. TMAH is an excellent dispersant. In our experiment, we used 0%, 1%, 2%, 4% and 8% TMAH to compare the effects of changing dispersant particle concentration on the magnetic nanobeads (see Fig. 3).

Results showed that the particle size was smallest when the Fe^{3+}/Fe^{2+} ion concentration ratio was 1.5:1 and the NH_3 concentration was 0.5 mol/L. The quantity of the dispersant and particle size confirmed a negative correlation; however, a decrease in particle size did not continue when the mass fraction was greater than 1%. Thus, the particle size was smaller when the fraction was 1%. Under such reaction parameter conditions, the particle size of magnetic nanobeads can reach approximately $10 \sim 10^2$ nm.

Cost analysis:

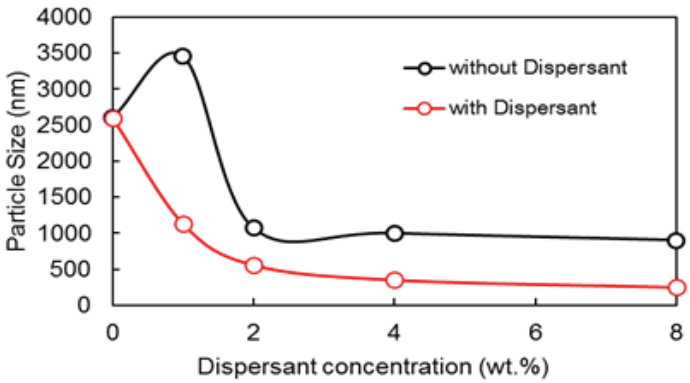

Fig. 3 Effects of the dispersant concentration on particle size.

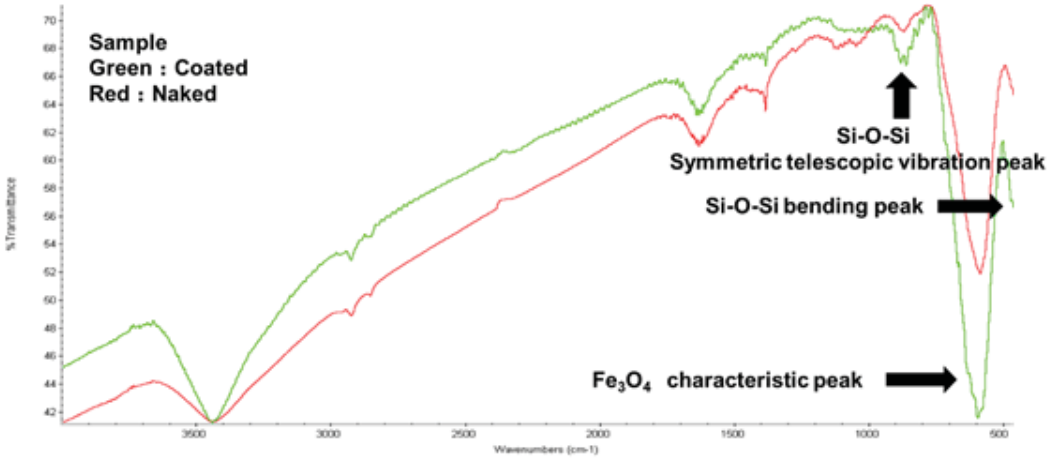

Fig. 4 Infrared spectrum of naked and coated magnetic beads.

It is necessary to make a cost analysis of self-manufactured magnetic nanobeads in a laboratory environment. The total cost was divided into four parts: chemical cost, instrument cost, dye cost and other costs. The chemical cost was as follows: 500 g $FeCl_2$ cost \$3 USD (1 USD = ~6.0 RMB). The remaining cost conversions followed the same pattern, namely, 500 g $FeCl_3$cost \$6.50 USD, 500 g NH_3 cost \$1.67 USD, 500 g anhydrous ethanol (absolute ethanol) cost \$1.8 USD, 100 g tetramethylammonium hydroxide cost \$13.3 USD, 500 g ethyl silicate cost \$5 USD. A one-time manufacturing process requires 1 g, 2 g, 2.9 g, 0.2 g, 0.1 g and 3 g of the aforementioned chemicals, respectively. Thus, the cost of the chemicals combined is \$0.017/g USD. Additionally, 25 g of crystal violet cost \$2.50 USD, although the cost could be compounded when purchasing the standard size solution (1250 mL). The standard safranin dye cost is \$4.17 USD, and 500 ml of Gram's iodine cost \$3.33 USD. The cost of the dyeing liquid for one experiment is \$0.003 USD. The three neck flask is the only instrument cost; however, after approximately four to six usages, the inner surface became stained with residue, which was difficult to remove, requiring it to be replaced. The remaining equipment does not require any input costs. Therefore, one three neck flask that can be utilized an average of five times at a cost of \$13.3 USD will cost \$2.67 USD per experiment.

As it pertains to dye and water costs, a single preparation produces 5 g $\pm$ 0.2 g nanobeads, which costs approximately \$3.33 USD, while the identification of microbes requires 2 mg/each time, and, taking loss and error into account, the one-time identification cost would therefore be \$0.003 USD, which is a cost-effective alternative.

FT-IR Result Analysis:

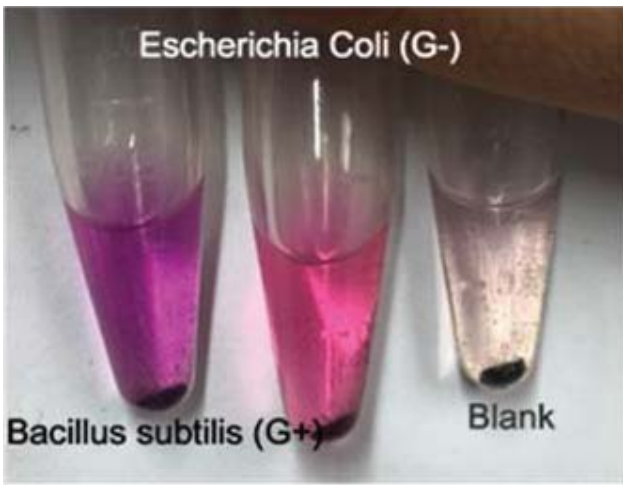

Fig. 5 Staining results of model bacteria.

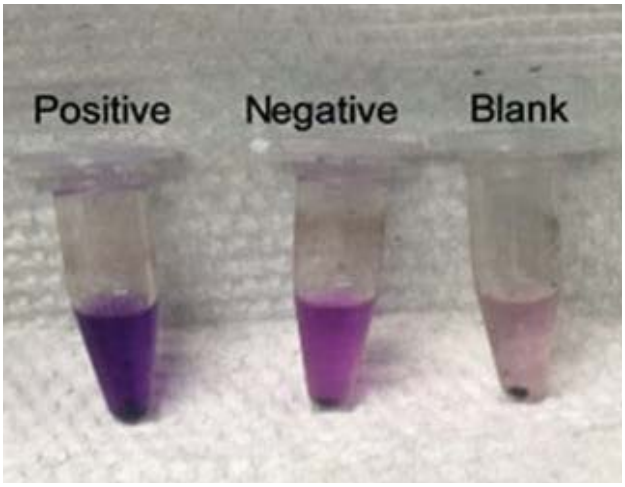

Fig. 6 Staining results of other: Positive, *Bacillus subtilis* (G^+); Negative, *Escherichia coli* (G^-); Blank, no bacteria present.

Fig. 4 provides a near-infrared spectra of Fe_3O_4 coated by SiO_2. This figure shows that the bending peak of Si-O-Si is 4 460 cm^{-1}, the characteristic peak of Fe_3O_4 is 580 cm^{-1}, and the symmetric telescopic vibration peak of Si-O occurred at wavenumber 800 cm^{-1}. The characterization of the infrared spectrogram indicated that SiO_2 had been successfully coated to the Fe_3O_4 magnetic nanobead surface through a chemical reaction.

4 Staining results

Model bacteria staining result:

For our experiments, we selected two model bacteria, namely, the well-developed X_3 (positive, not sequenced) and the X_5 (negative, *Klebsiella pneumoniae*, *Klebsiella* root subsp. Root MGH 78578), and they were joined to the blank group (with microbes using equal amounts of ultrapure water), while the remaining steps were the same. Dyeing was conducted according to the above process in accordance with the X_3, X_5, blank group order from left to right. Results are provided in Fig. 5.

In Fig. 5, the left flask displays a purple color, the middle displays a red color, and the right flask displays a very pale pink color. In view of the fact that magnetic nanobeads may potentially adsorb the safranin dye solution, we concluded that the left flask was Gram positive, the middle flask was Gram negative and the right flask contained no bacteria. This is consistent with known facts and confirms that this experimental staining test method can produce effective discrimination results by means of color alone.

Other bacterial staining result:

A study by Qiu et al. (2006) indicated that the magnetic nanobeads have the capacity to adsorb various bacteria, such as *Escherichia Coli*, etc. Relevant experiments have stained some common microbes, such as *E. Coli* (G^-), *Bacillus subtilis* (G^+), *Staphylococcus aureus* (G^+) and *Enterococcus Faecalis* (G^+). Staining results were consistent with known facts, and they confirm the accuracy of this method. Results are shown in Fig. 6.

Blind experiment staining result:

In order to apply this method to current scientific research, it is necessary to simulate real-world conditions and conduct tests under blind experiments. Namely, bacteria were randomly selected from the microbe pool (not excluding the potential of repeating the same bacteria), and the selection scheme was recorded. Bacteria were sent to testers who were not informed as to the content of samples (blind), and the samples were then identified according to the above process. The final test results were then compared to the selection scheme to verify the

accuracy and feasibility of this method. One test result is provided in Fig. 7.

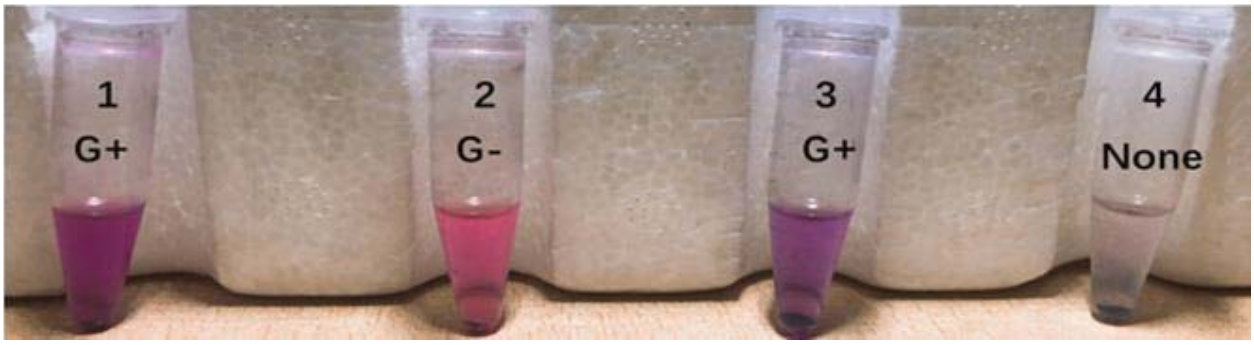

Fig. 7 Staining results from the blind experiment: No. 1, *Bacillus subtilis* (G^+); No. 2, *Escherichia Coli* (G); No. 3, *Enterococcus Faecalis* (G^+); No. 4, blank.

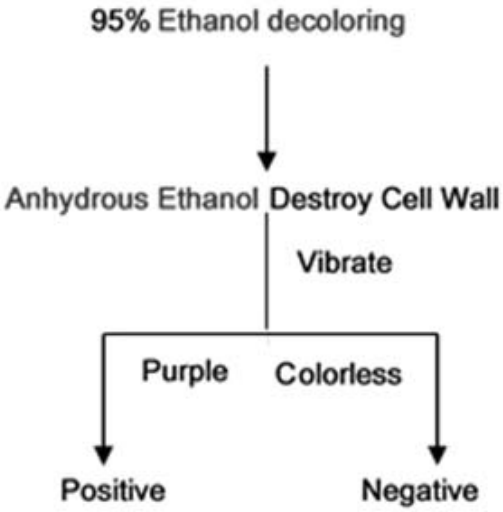

Fig. 8 Optimized staining process (bacteria confirmed).

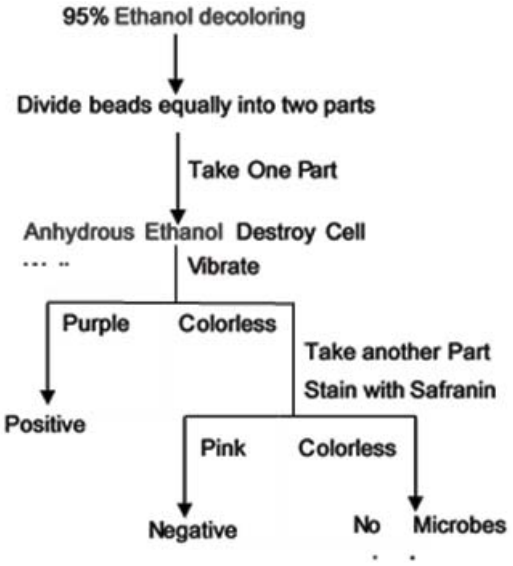

Fig. 9 Optimized staining process (bacteria unknown).

5 Discussion and optimization

Blank group color phenomenon:

The phenomenon of the very pale pink color in the blank is due to the adsorption effect of magnetic nanobeads on the dye solution and the long settling time of the dye solution caused precipitation, whereby the small dye particles block the magnetic nanobead layer and affect color rendering. It is difficult to wash out dyed liquid particles using only a limited number of washings, which consequently led to the very pale pink color of the blank control group. The crystal violet that adsorbed onto the magnetic beads will be removed during the decolorizing step. Furthermore, given that the very pale pink color does not affect the dyeing conditions of bacterial resumption on the magnetic beads, we did not find it necessary to remove the color. In this study, we provided two optimization steps, using a 0.45 mm filter membrane to filter the dye solution, removing solid particles, and increasing the washing time to clean dyes more effectively. In addition, reducing dye concentrations,

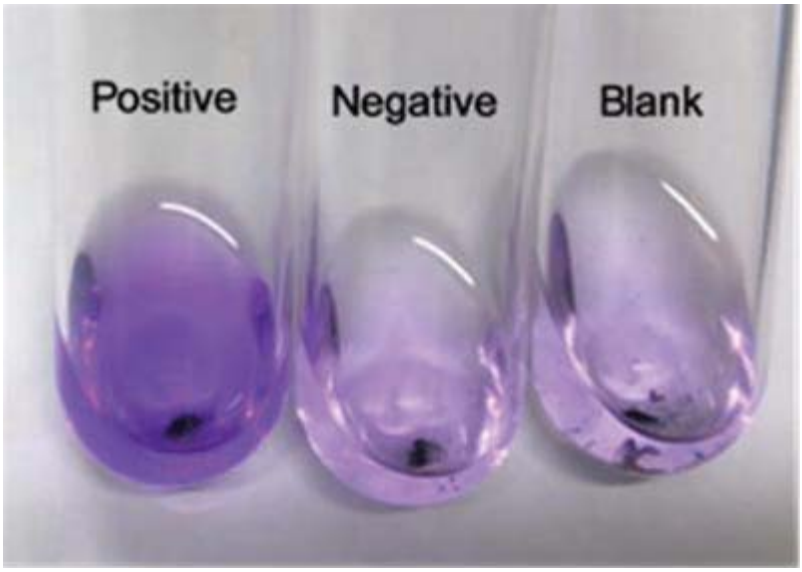

Fig. 10 Staining results from optimized steps.

which reduces the amount of dye molecules entering into the centrifuge tube, can also diminish the influence of dye adsorption on color.

Dye Optimization

An effective way to determine whether bacteria are present in culture liquid is to observe the transparency daily. This study provides a faster detection method when the minimum value of bacterial concentration is detectable (confirmed) in the culture liquid. Previous steps are the same as the process discussed above, namely, after the decolorizing step, omit the re-dyeing step, directly add anhydrous ethanol (absolute ethanol) to destroy cell walls and allow the outflow of cytoplasm. Following this, observe the color. If the color is dark purple, it is G+ (Gram positive), if colorless, it is G- (Gram negative). There are also processes designed to test culture liquid when uncertain whether bacteria are alive. Two specific processes are shown in Fig. 8 and Fig. 9. Test results are shown in Fig. 10.

Optimization of weighing nanobeads:

According to tester feedback, weighing nanobeads accurately on a milligram scale is difficult. However, we provide a method to measure nanobeads on a miniscule scale. Because the diameter of nanobeads are between $10\sim10^2$ nm, they belong to colloidal dispersion, which can disperse stably in water. Testers can convert weight measures into volume by mixing nanobeads with water. For instance, if 2 mg of nanobeads are required, 100 mg of nanobeads should be weighed out and mixed with 1000 mL of water and stirred until it forms a colloidal solution. Following this, absorb 20 mL of the solution using a pipette. By pouring out water under external magnetic control, the correct weight of nanobeads will remain in the container.

6 Conclusions and expectations

The experiment conducted by this study was convenient and easy to carry out, and it can be run without the need of a fire source or electricity. Moreover, its overall cost is low, its experimental duration is short and it requires less instrumentation to perform. Furthermore, results from the experiment were clear and easy to analyze, and the magnetic nanobeads can be reused after washing. It is also a suitable technique to use to introduce and perhaps popularize in teaching experiments designed for college students.

This method can be applied to scientific research by designing a reagent kit for the same experimental purpose. The magnetic nanobeads and requisite dyeing liquid can be packaged into several disposable doses,

and scientists can familiarize themselves with this new method by following a complementary instruction book.

Acknowledgments

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Modeling of a Small Scale Wind Turbine for Water Pumping Process: Case Study

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Abstract

This paper deals with the study of a small scale wind turbine implementation for agricultural isolated location. Indeed, the electrification of these locations for industrial and agricultural requirements remains one of the largest current projects, especially when dealing with the use of sustainable sources such as solar, hydro and wind power. The main aim of this work is to validate the feasibility of using wind turbine in this location and to evaluate the performance of the excess energy storage capacity, which in this case is stored as water under the potential energy form. The study represented in this paper has been performed under the case of pumping water station using wind turbine in an isolated location at the north of Algeria, considering that this site fulfills the requirement of a favorable wind potential and a permanent water source. The design of the used wind turbine is based on the constraints of the climate data of the selected location and the lower cost of the implementation means, whereas, the water tank dimensions are is optimized with respect to the daily water consumption data and the available excess of energy to be stored and to be used later for water pumping during the period of wind absence.

Nomenclature

V_w Wind velocity
P_w Wind mechanical power
λ Tip speed ratio
θ Pitch angle of rotor blades
C_p Coefficient of performance which is a function of λ and θ
R_p Rotor blade swept area where r is rotor radius (m^2)
G Gear ratio
q_{out} Output flow rate, V_{opr} Operating voltage

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$V_{\min}$ Minimum voltage
H Height of water in the tank
$H_{\max}$ Maximum height of water in the tank
ρ Air density
W_G Generator rotor speed
T_W Torque on high speed shaft
T_e Generator torque
T_{loss} Loss torque
T_w Generator torque
q_{ref} Referential flow rate of the pump

1 Introduction

For many centuries, wind and waterfalls have been used to transform wind and water mills to grind maize or transport water, but after discovering fossil sources such as coal and oil, these sources gradually fail until man finds that fossil fuels have caused various dangers, especially the environmental aspect (Zhu et al., 2015). Recently, the mode faced with the reduction of consumption of fossil sources, through the development of sustainable sources as for wind energy technology. Small scales of photovoltaic and wind turbines are usually used in urban areas.

Many researchers have made significant contributions focusing on the ecologic aspect in one side and efficiency improvement of this technology in the other side. Cooney et al. (2017) have characterized the performance of an urban wind turbine based on real data, in the same context Sam Sichilalu et al. (2017) have proposed an optimal control strategy of heat pump water powered by PV and Wind. Wang and Teah (2017) studied the life cycle of horizontal-axis wind turbines at Small scale. De Lellis et al. (2016) have investigated on the economic aspect of the production of electricity by wind turbine and PV with pumping of water, also for the references (Pérez-Díaz and Jiménez, 2016; Zhang et al., 2016) most of their works is focalized on the optimization of wind energy. Certainly these works have confirmed that the use of wind in urban environment is a recent and potential field with such advantages.

Wind resources are used in several sectors, including the agriculture, it is due to the complications of power network connection and the high energy demand associated with these activities. Indeed, wind energy production could be conserved in the form of electrical energy or stored in water energy reservoirs; these two forms of energy can be used for daily life need. In this work, an irrigation system is modeled, in order to determine the optimum factors of the hydraulic efficiency of this system. This system consists of a small scale wind turbine as primary source of electricity, the storage of this electricity is performed by cell battery. The system contains also a water pump to supply the water reservoir. This pumping system gives an advantage of no need of it possible to store electrical energy in the farm (water flows from the reservoir to the farm without electrical power consumption as it falls directly from the reservoir by its own potential gravity).

2 Small scale wind turbine

The principle of wind turbines is to transform the kinetic energy of wind through a set of blades that are directly connected to a generator. There are basically two families of wind turbines, the horizontal axis and the vertical axis wind turbines. They are generally composed of blades, generator, the tower and the mechanical transmission components. Figure 1 shows the performances coefficient of various designs in wind rotors.

Theoretically, when the blades are more numerous, the efficiency improve more. But some cases present contradictive results, which is explained by the correlation of less bales makes the turbine turns quickly and therefore avoid the noise generated and the mechanical wear of rotating parts (Ringwood and Simani, 2015).

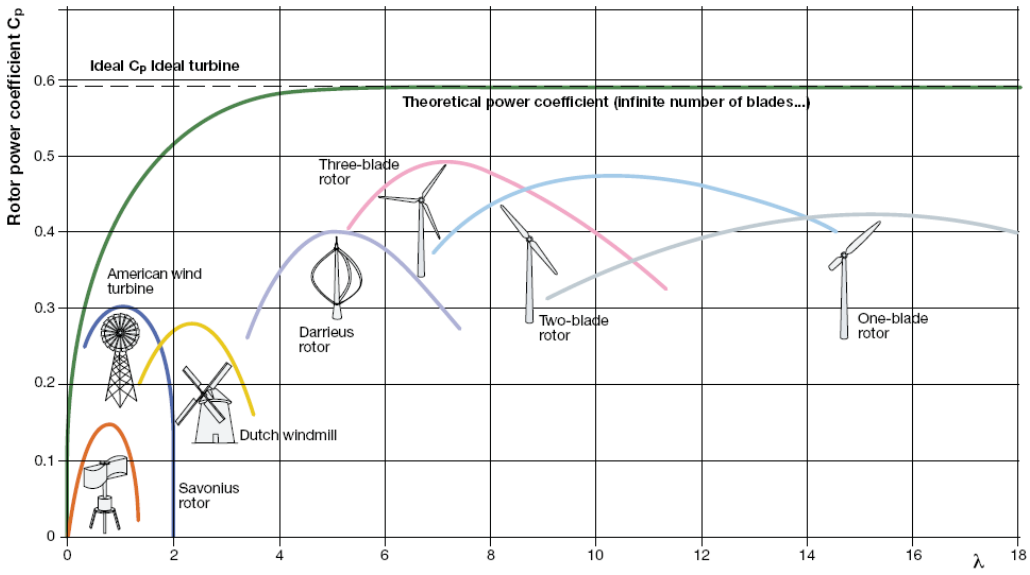

Fig. 1 Performance coefficient of various designs of wind turbine rotors.

Where the generator component, as shown in Figure 2, is the part that produce electricity, via converting mechanical power of bales there exists two model, synchronous and asynchronous machine It may be a dynamo (product DC) or an alternator (Product AC) (Bouzidi, 2011; Mahjoubi et al., 2014). The tower component in small scale wind turbine is one of the most important parts, shown in Figure 3, it is not just a support structure. It raises the wind turbine so that its blades safely clear the ground and so it can reach the cleaner, stronger winds at higher elevations. There are several types of towers such as:

- **Tubular Steel Towers:** These types are used in all most large wind turbines
- **Lattice Towers:** they are manufactured using welded steel profiles. The basic advantage of lattice towers is the low cost.
- **Guyed Pole Towers:** All most the small wind turbines are built with narrow pole towers supported by guy wires
- **Hybrid Tower:** They are made in different combinations of the aforementioned types.

Matching the small scale wind turbine speed from its low to the required levels is ensured by a mechanical transmission system which includes:

- **Contact gears:** they are used for transmitting torque and speed at different increasing ratios. they have two main constraints, a complex design is required for the gears system which makes them more expensive to be manufactured and an expensive lubrication is required,
- **Transmission belt:** is a loop of flexible material used to link two or more rotating shafts mechanically. Belts may be used as a source of motion, to transmit power efficiently, or to track relative movement (Zhu et al., 2015). The efficiency of belts is reduced by 0.5-1% due to belt slip and stretch. Some typical belt types are Veer belts, timing belts, multi-groove belts,
- **Chain drives:** Power transmission chains are commonly found in bicycles and motorcycles. Noise is usually higher than with belts or gears, but silent chain drives are relatively quiet and Long shelf life because metal chain ordinarily doesn't deteriorate with age and is unaffected by sun, reasonable ranges of heat, moisture, and oil.

Fig. 2 Generator component of small scale wind turbine.

Fig. 3 Tower component of small scale wind turbine.

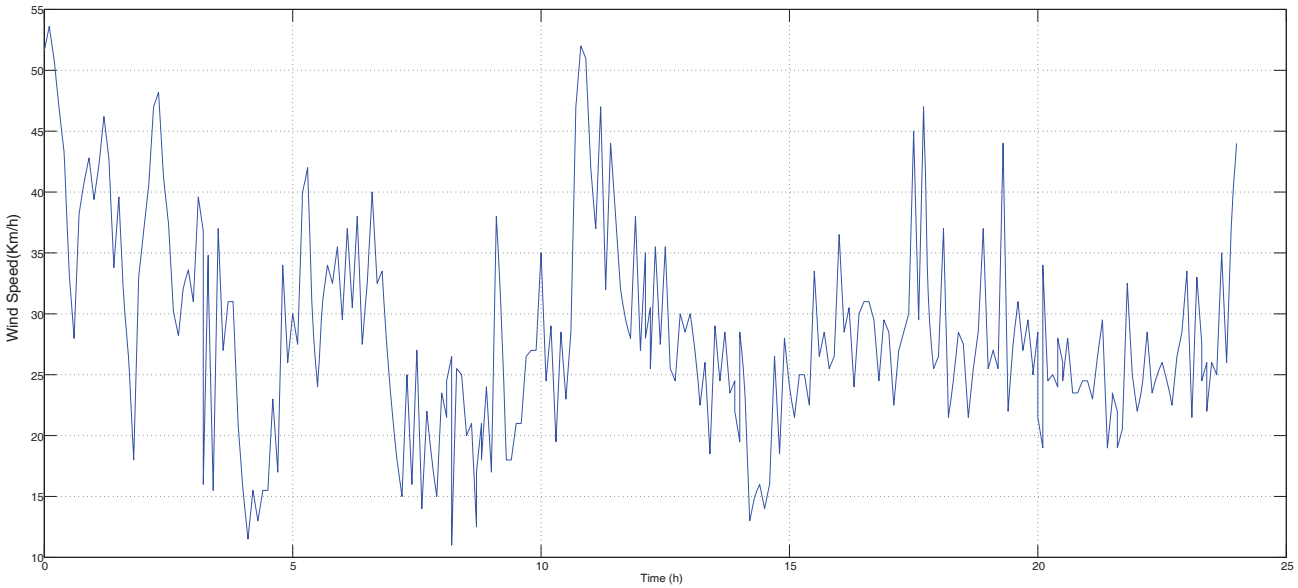

Fig. 4 Variation of the wind speed during one day.

3 Design and configuration of the realized wind turbine

Choosing the right configuration must first include the database of the study in order to design a compatible shape, feasible and less expensive. In this work the studied location is an Algerian town of Boumerdes called Ammal, located 50 km from Algiers, Tizi Ouzou and Bouira, in the west of Kabylie 36°38'05" North 3°35'26" East. Ammal is a rural location with agricultural vocation and it is a windy area especially in winter and spring period.

The curve below shows the variation of the wind speed during a windy day in the month of February 2016 as shown in Figure 4, due to the reference (Copal et al., 2013).

The designed wind turbine consists of 4 wooden blades made from recovered damaged tables, as shown in Figure 5. Transmission and multiplication of the speed is performed by belt, in a manner so that the large aluminum wheel multiplies the speed of the alternator. The system is equipped with a wind vane which is used

Fig. 5 Small scale wind turbine before and after realization.

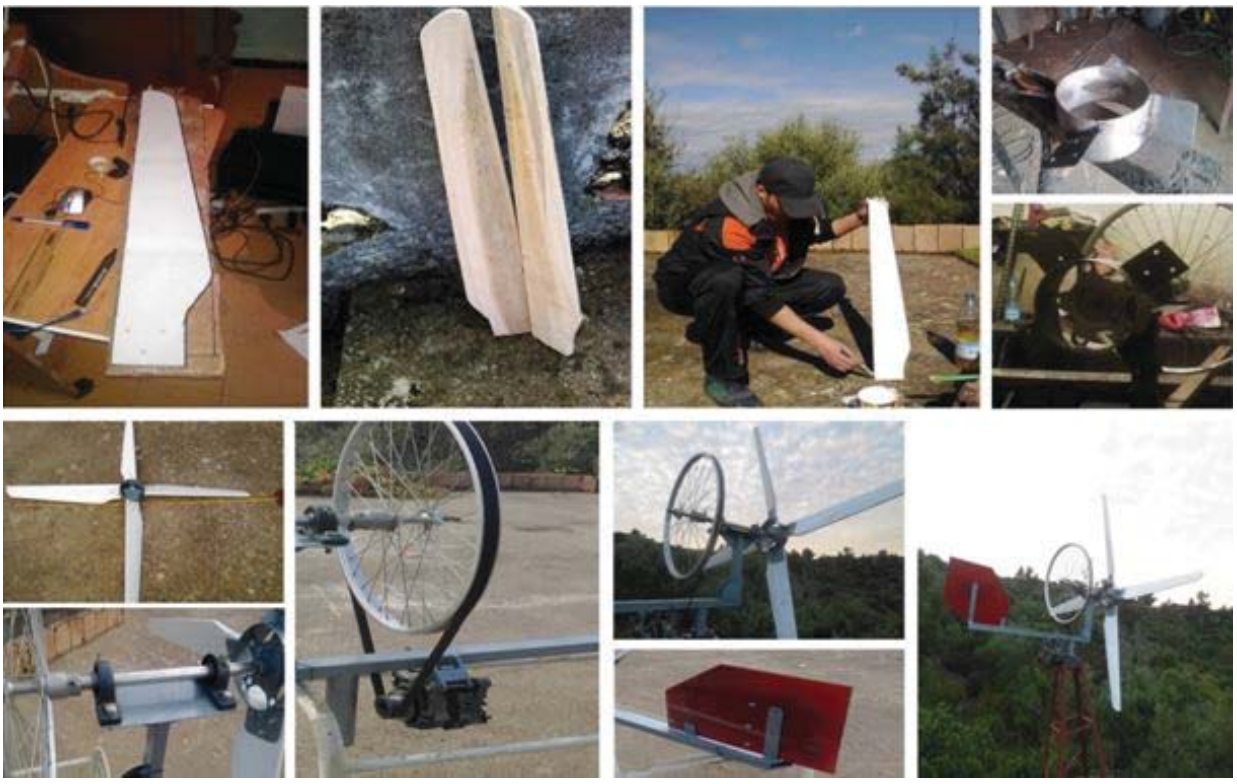

Fig. 6 Realization steps of the designed wind turbine.

to direct the turbine towards the optimal direction of wind, whereas the brake system in this case is performed manually by the isolation of the transmission between the turbine and the generator. The primitive design prototype was made by 3D design software. Simulation software was also explored for performance analysis to introduce the necessary improvements. Figure 6 shows the realization steps of the designed wind turbine.

The chosen configuration is intended for an agricultural need for pumping water from a well to a planted land, it consists of the manufactured wind turbine, the batteries, DC/AC inverter, water pump and the water tank.

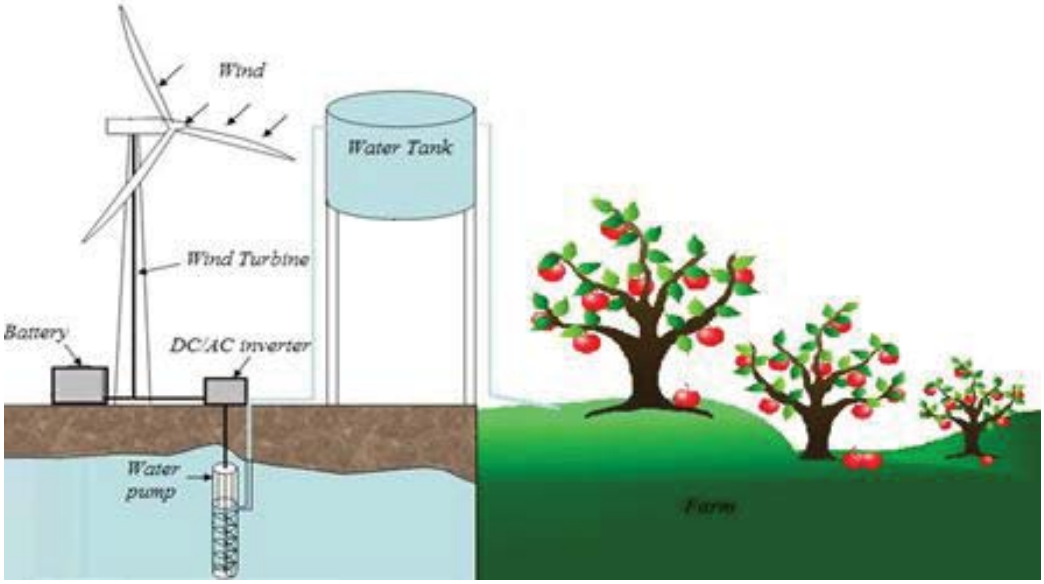

Fig. 7 Scheme of the studied system.

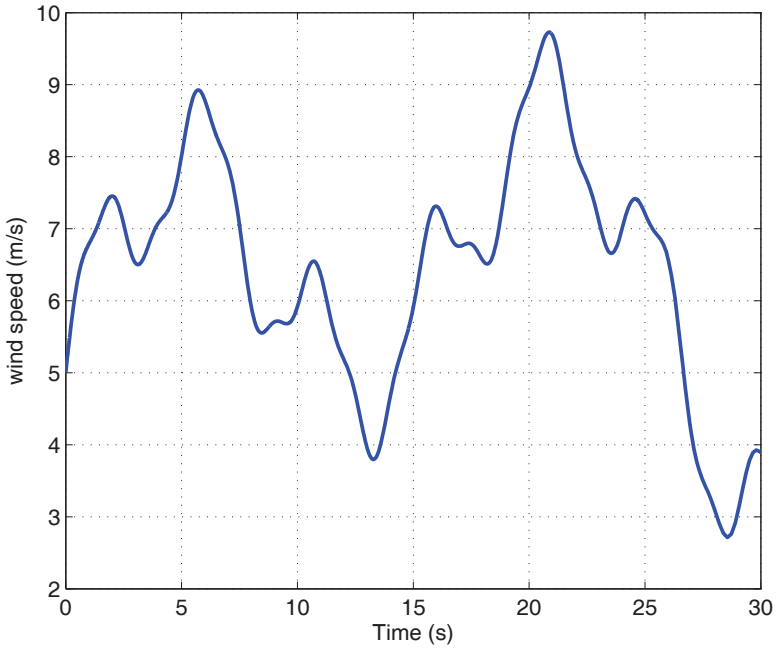

Fig. 8 Wind speed profile.

Nominal velocity of wind turns the wind turbine to produces continuous current via a generator; this voltage will be converted into alternative voltage 220V 50Hz through a DC/AC inverter, the obtained Ac voltage is applied to the water pump which pumps the water from well to the tank placed at a higher level from the ground with an approximate height of 10 m.

The stored water will take a gravity force which facilitates its supply to the land. Part of the energy produced can be stored in batteries once the water level reaches the maximum, this energy can be used when the wind speed is decreasing. In future approaches, this system can be equipped with a hydroelectric turbine which takes advantage of the waterfall to produce electricity that can compensate the lack of wind speed. Figure 7 shows the different components of this chain and its operating principle.

4 Modeling of the chosen configuration

4.1 Modeling of wind velocity

The opted configuration of designed wind turbine will be modelled for its principal components, this system includes: the wind velocity, the wind turbine and the mechanical part. For wind velocity modelling, it is clear that the wind resource is dominant in a wind power scheme and so decisive for the estimation of production of electricity and profitability. The dynamic properties of the wind are vital for the study of the entire system of energy conversion as the wind power under optimal conditions is a function of the cube of the wind speed as shown in Figure 8. On the other side the random wind velocity oscillations are based on the sinusoidal functions given by:

$$V_w = 4 + 2\sin(\frac{\pi t}{30}) + 2\sin(\frac{3.5\pi t}{30}) + \sin(\frac{12.35\pi t}{30}) + 0.2\sin(\frac{35\pi t}{30}). \tag{1}$$

4.2 Modelling of wind turbine

In order to estimate the power production by the wind turbine, we established a model that is defined by the wind speed V_w, the calculation of the power production passes by two steps:

4.2.1 Mechanical part model

The mechanical part is formed of the turbine which converts the kinetic energy into mechanical energy and the step-up gear which is the intermediary between the electrical and mechanical part and aerodynamic power here is given by:

$$P_w = \frac{1}{2} \cdot C_p \cdot (\theta, \lambda) \cdot \rho \cdot \pi \cdot R_p^2 \cdot V_w^2. \tag{2}$$

Such that the air density is $\rho = 1.3$ kg/m^3

$$\begin{aligned} \lambda &= \frac{R_p \cdot W_G}{V_w}, \\ T_w - T_e - T_{loss} &= J\frac{dW_G}{dt}, \\ W_G &= \frac{1}{J}(T_w - T_e - T_{loss})dt. \end{aligned} \tag{3}$$

The coefficient of performance C_p is given by a simplified model as follows:

$$\begin{aligned} C_p(\lambda, \theta) &= C_1(\frac{C_2}{\lambda_1} - C_3 \cdot \theta - C_4) \cdot e^{(\frac{-C_5}{\lambda_1})} + C_6\lambda_i, \\ \frac{1}{\lambda_i} &= \frac{1}{\lambda + 0.08 \cdot \theta} - \frac{0.035}{\theta^3 + 1}, \end{aligned} \tag{4}$$

where $C_1 = 0.5716$, $C_2 = 116$, $C_3 = 0.4$, $C_4 = 5$, $C_5 = 21$ and $C_6 = 0.0068$.

In order to observe the curve of the characteristic (specific speed and power coefficient), shown in Figure 10, the value of θ and the constants C was varied and it is supposed that the average wind speed is $V_w = 8$ m/s and the pitch angle is $\theta = 3°$. To estimate the optimal performance coefficient $C_{p\ opt}$ and the optimal specific speed λ_{opt}.

The wind turbine converts wind velocity to mechanical power attainable from the wind, this conversion is based on the equations given before and the satisfaction of the generator rotation is verified by the equation below:

$$T_w = \frac{P_w}{W_G} = \frac{\rho \cdot \pi \cdot R_p^2 \cdot (\theta \cdot \lambda) \cdot W_G^2}{2\lambda^2 G^3}. \tag{5}$$

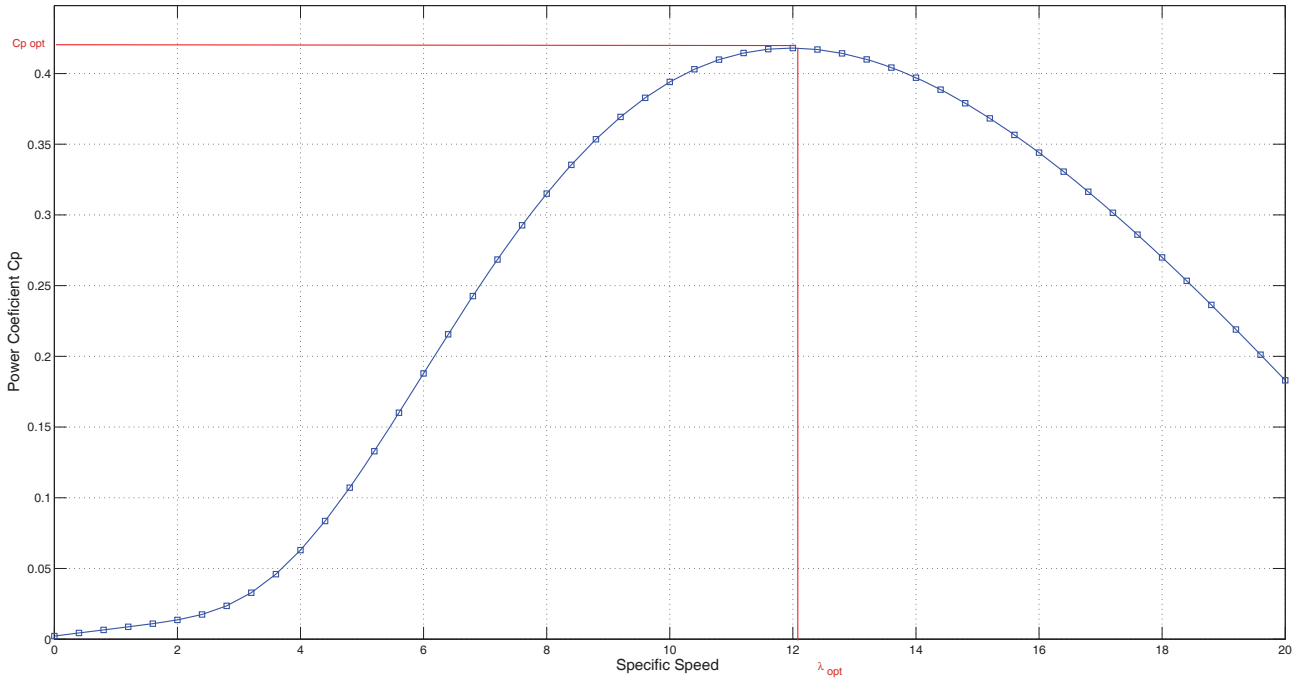

Fig. 9 Power coefficient characteristic.

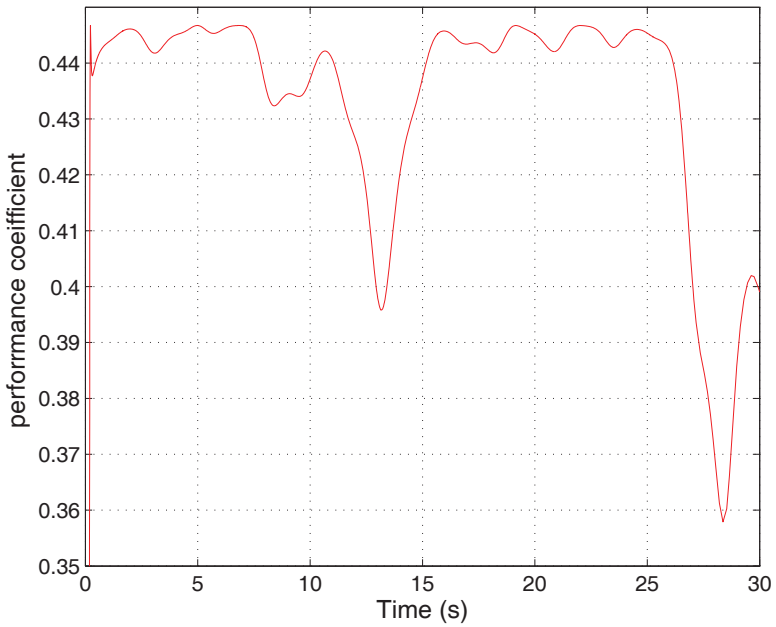

Fig. 10 Performance coefficient of the turbine model.

In fact, the drive train in this system converts wind speed to the generator shaft, Figures 10, 11, 12 and 13 represent simulation results due to the parameters of mechanical part model given in table 1 with wind speed variation, the inertia of the turbine blades is taken from literature results with the same design where its value

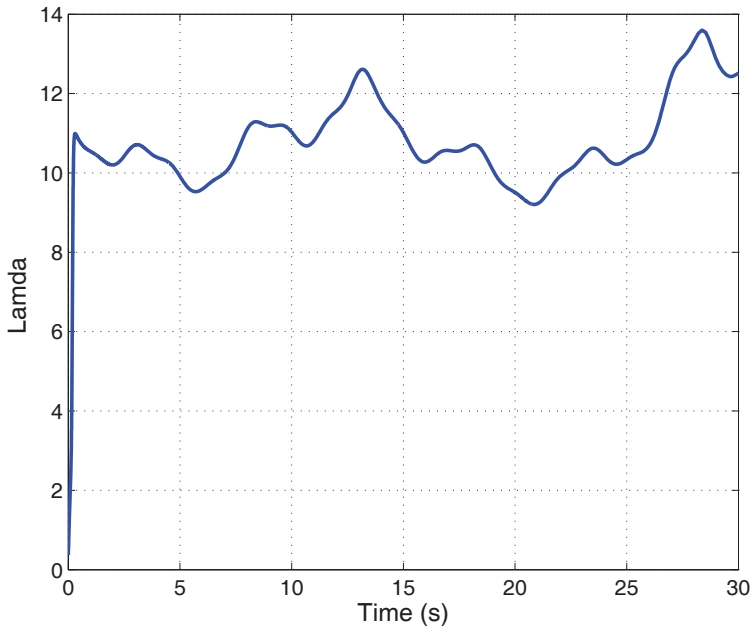

Fig. 11 Variation of tip speed ratio.

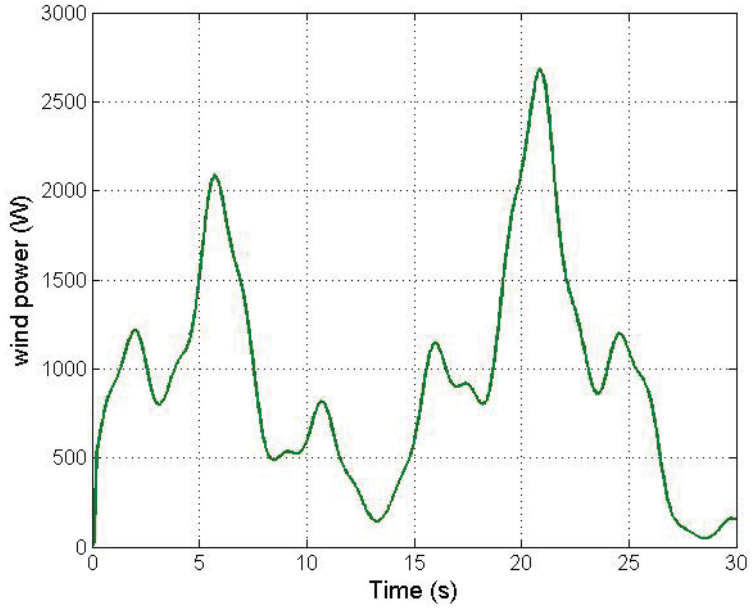

Fig. 12 Wind power.

has some effect on the alternator shaft speed, given as follows:

$$W_G = \frac{1}{J}(T_w - T_e - T_{loss})dt$$
$$P_e = \frac{P_w}{W_G} = \frac{\rho \cdot \pi \cdot R_p^5 \cdot C_{p\ opt} \cdot W_G^3}{2\lambda_{opt}^2 G^3} \tag{6}$$

with $P_{loss} = P_e - P_{opt}$ and $P_{opt} = I_{out(\text{opt})} - V_{out(\text{opt})}$.

Figure 10 represents the variation of the performance coefficient C_p over time, its value varies between 0.425 and 0.445, it reaches a limit of 0.405 which is justified by a lower wind speed at time between 27s to 29 s. Figure

Table 1 Parameters of mechanical part model.

Parameter	Connotation	Value
Air density	ρ	1.3 kg/m^3
Turbine radius	r	1.75 m
Gear ratio	G	8°
Optimal output current	$I_{out(\text{opt})}$	80 A
Optimal output voltage	$V_{out(\text{opt})}$	12 V

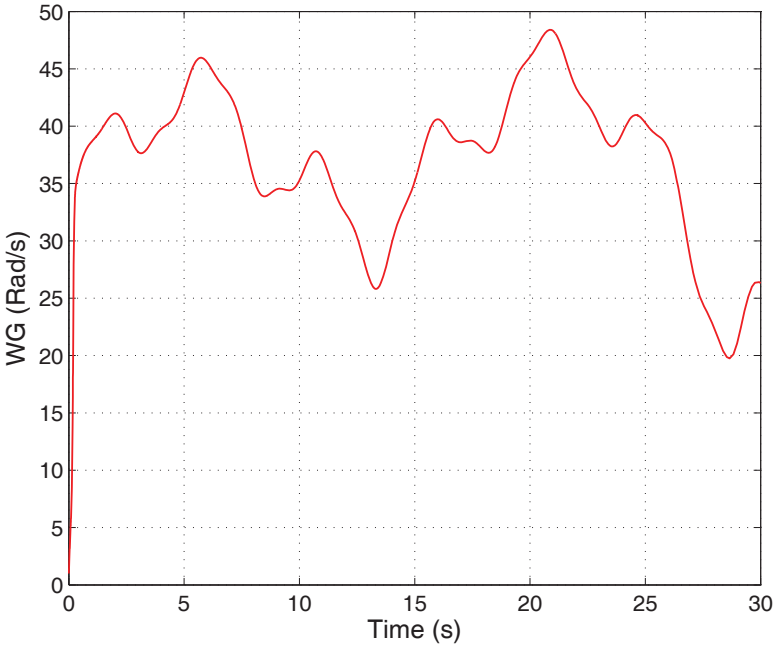

Fig. 13 Generator rotor speed.

Table 2 Parameters of electrical part.

Parameter	Connotation	Value
Reference voltage	C	13.2V
Rectifier diode	D	1.2V
Initial temperature	T	25c°
Nominal voltage	$V_{Nom(Hatt)}$	12V
Ampere hour rating	AH	120A
losses constant	K_p	100
Initial resistance	R_i	0.05 hm

11 represents the variation of the tip speed ratio which is stable compared to the coefficient P_c, tip speed value in this case varies between 10 and 12.

Figure 12 represents the variation of the wind power obtained, it depends directly on the wind speed and the C_p coefficient; its value varies between 500 and 3000 W with an average value of 1800 W. Figure 13 represents the generator rotor speed, its value is given between 30 and 50 rad/s with an average value of 45 rad/s.

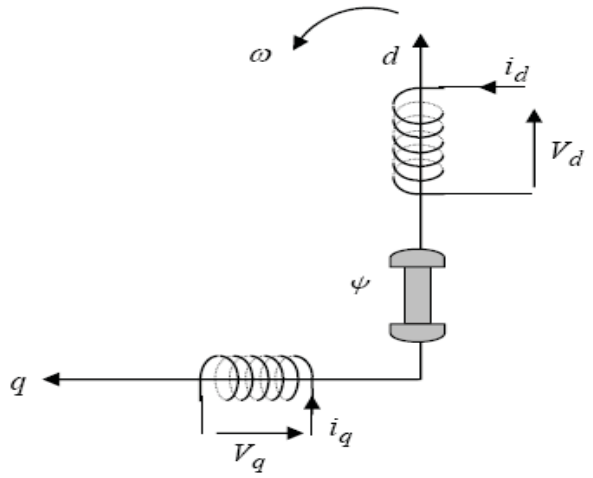

Fig. 14 Alternator representation.

4.2.2 Electrical part models

The electrical part consists of the alternator (car alternator is used in this study) which converts mechanical energy into electrical energy, it is equipped with a voltage regulator which controls the voltage at the output of the alternator. Parameters of the electrical part are given in Table 2.

A. Alternator

The analysis of synchronous machine (alternator) model is simplified by Park's mathematical transformation which was introduced in 1992 (Campana et al., 2013; Huang et al., 2015). In the three-phase systems, the phase quantities which include stator voltages, stator currents, and flux linkages, are time varying quantities. By applying Park's transformation the three phases a, b, c frame can be transformed to two axis frame dq as follows (De Lellis et al., 2016; Tummala et al., 2016):

$$\begin{bmatrix} u_d \\ u_q \\ u_0 \end{bmatrix} = \begin{bmatrix} \cos(\theta_r) & \cos(\theta_r - \frac{2\pi}{3}) & \cos(\theta_r + \frac{2\pi}{3}) \\ -\sin(\theta_r) & -\sin(\theta_r - \frac{2\pi}{3}) & -\sin(\theta_r + \frac{2\pi}{3}) \\ \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix}. \tag{7}$$

The inverse Park's transformation is given by:

$$\begin{bmatrix} u_a \\ u_b \\ u_c \end{bmatrix} = \sqrt{\frac{2}{3}} \begin{bmatrix} \cos(\theta_r) & -\sin(\theta_r) & \frac{\sqrt{2}}{2} \\ \cos(\theta_r - \frac{2\pi}{3}) & -\sin(\theta_r - \frac{2\pi}{3}) & \frac{\sqrt{2}}{2} \\ \cos(\theta_r + \frac{2\pi}{3}) & -\sin(\theta_r + \frac{2\pi}{3}) & \frac{\sqrt{2}}{2} \end{bmatrix} \begin{bmatrix} u_d \\ u_q \\ u_0 \end{bmatrix}. \tag{8}$$

Based on the equivalent circuit of the alternator in dq frame as shown in Figure 14, The differential equations modeling the alternator can be expressed as follows:

$$\begin{aligned} V_d &= -R_s i_d - L_d \frac{d}{dt} i_d + w L_q i_q, \\ V_q &= -R_s i_q - L_q \frac{d}{dt} i_q + w L_d i_d + w \psi_f. \end{aligned} \tag{9}$$

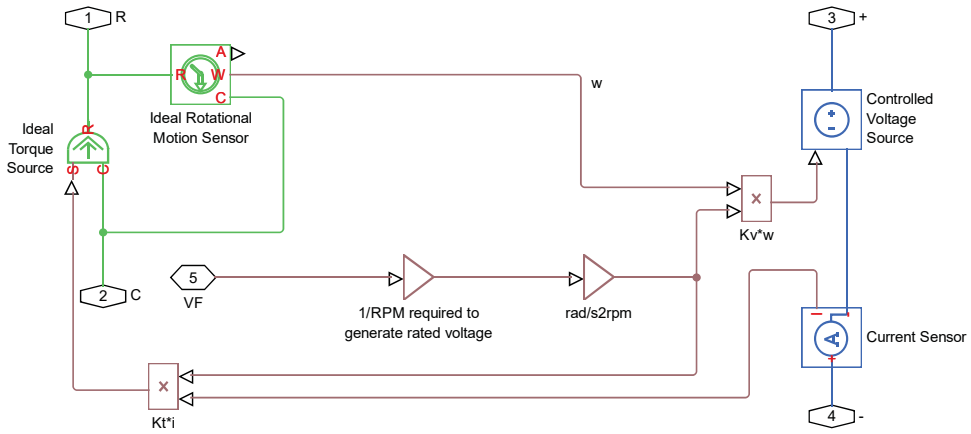

Fig. 15 Alternator mode.

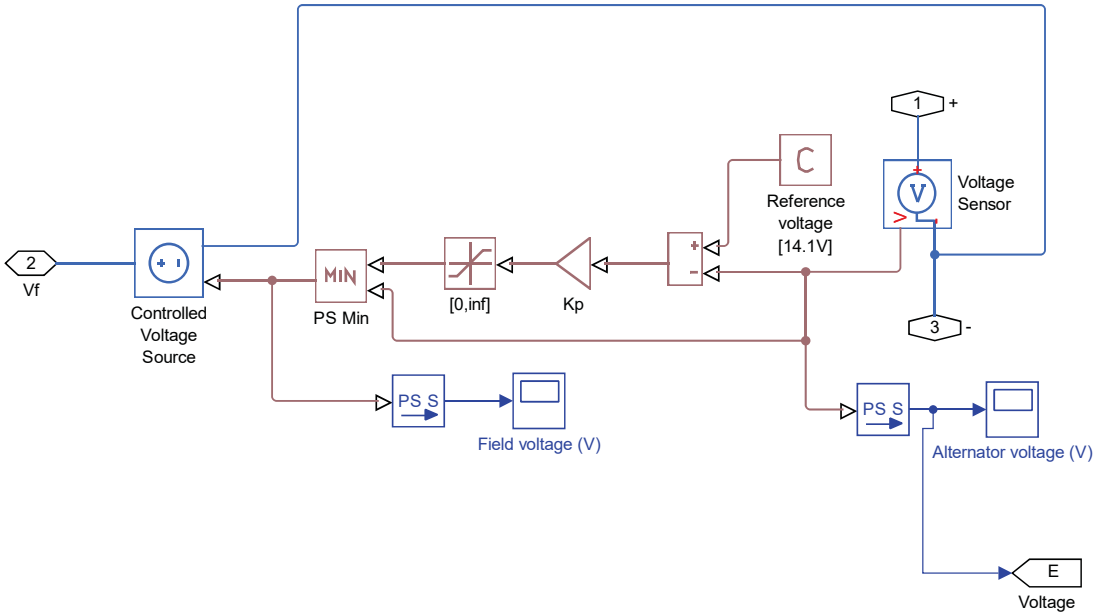

Fig. 16 Voltage regulator model.

On the other side, the modeling of the load following the dq frame is expressed as follows:

$$V_d = -R_{ch} i_d - L_{ch} \frac{d}{dt} i_d + w L_{ch} i_q,$$
$$V_q = -R_{ch} i_q - L_{ch} \frac{d}{dt} i_q + w L_{ch} i_d. \tag{10}$$

The alternator circuit representation in Simulink of the present study block is shown in Figure 15, this model represent the mathematical function of rotational speed of the turbine linking with conversion to rad / s2rpm and the regulated voltage V_f.

B. Battery Model

The battery is used in this configuration to ensure the excitation of the alternator and the energy storage (generic battery) The battery model is represented as follows:

$$V = V_0[1 - (\frac{\alpha(1-x)}{1-\beta(1-x)})], \tag{11}$$

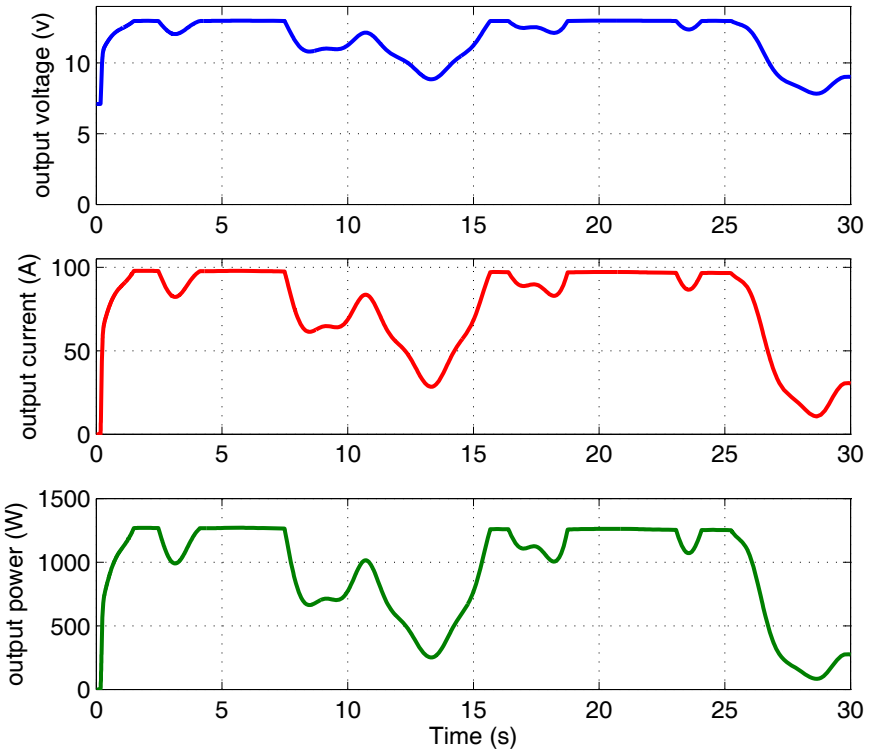

Fig. 17 Output data of the generator.

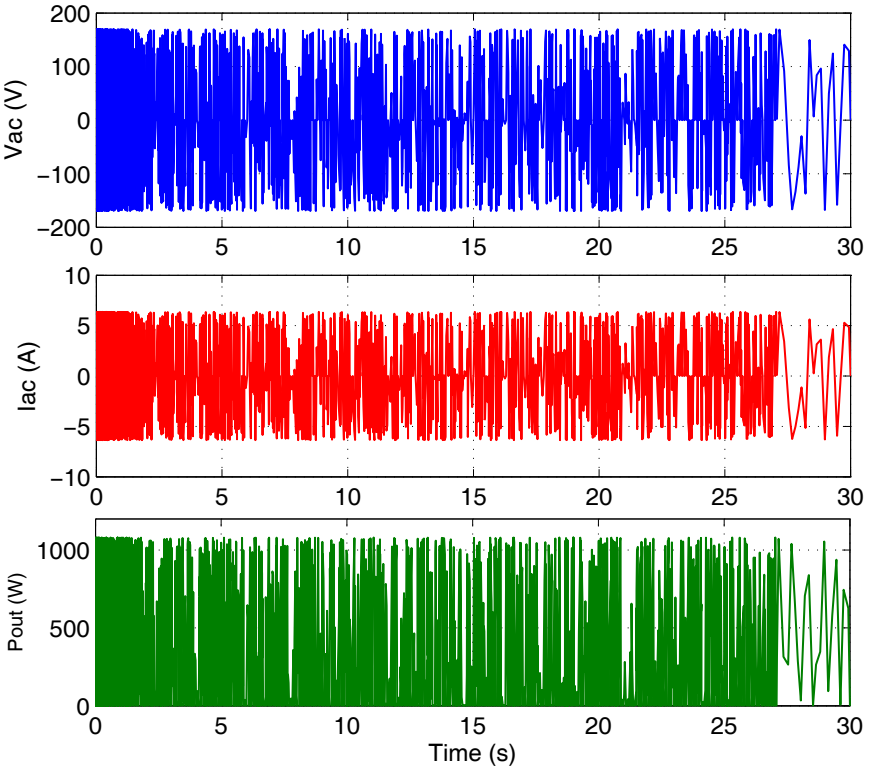

Fig. 18 Output data of the DC/AC converter.

where x is the ratio of the ampere-hours left to the number of ampere hours, (AH), for which the battery is rated, V_0 is the voltage when the battery is fully charged following the nominal voltage.

The established configuration of the battery model has to satisfy the following conditions:

- The voltage is zero when the charge is zero that is when $x = 0$,
- The battery voltage is V_1 (the voltage $V_1 \prec V_{nominal}$ when the charge is AH1 parameter value) when the charge is the charge AH1 when no load are V_1 parameter value, that is when $x = AH1/AH$.

C. Voltage regulator model

The voltage regulator model is shown in Figure 17, this model is simplified to calculate the output voltage V_f depending to the battery voltage V and the constant C that represents the reference voltage, this model depend also on the function of the losses constant K_p:

$$V_f = \min_V \lfloor (C - V)K_p \rfloor \tag{12}$$

D. DC/AC converter model

Several converter models are existing in the literature (Naci, 2003; Ofordile et al., 2014; Belabes et al., 2015; Tummala et al., 2016); in this paper, simplified model was chosen in order to ensure see the output power variation , the following equations were used for in this model:

$$\begin{aligned} V_{ac} &= F_i \cdot V_{ref}, \\ I_{ac} &= F_i \cdot I_{ref}, \end{aligned} \tag{13}$$

with $F_i = \frac{2\pi}{F_{ref}}$ and $P_{out} = V_{ac} \cdot I_{ac}$.

Figure 17 shows the output data of the wind turbine generator, in the first step the output voltage curve which is given by an average of 12 volts (DC), it can be observed that the voltage dip to 9 volt due to the low speed of wind and this is similar for the electric current that reaches 30A as shown in the second curve, the current here is given by an average of 90 A. the 3rd curve represents the variation of generator output (electrical power); it depends on the voltage and the electric current, it is given by an average of 1000 wats but it dip to 300 watts at the 14th second also at 28th second due to the current and voltage drop.

Figure 18 represents the variation of alternative current and voltage also power at the output of the DC/AC converter. The first curve represents the voltage variation which is varying between ($\pm$200v), the second curve represents the current variation which is varying between ($\pm$6 A), the last curve represents the variation of output power which is characterised by an average value of 780 wats. Usually a passive filter with capacitor is used to stabilize the output power.

4.3 Water pump and storage model

There are various mathematical model of water pump such as centrifugal pump and jet pump, where generally their models depend on the primary flow rate, the output flow and the diffuser area. In this study the choice of the water pump depends on the power production, the daily water demand and the level of water tank. A simplified mathematical model was used to model the behavior of the pump during the day following equation (13), its parameters are given in Table 3.

$$q_{out} = V_{opr} \cdot H \cdot q_{ref}. \tag{14}$$

The curve shown in Figure 19 represents the variation of water pump operation over the time. The pump has two malfunction periods at the instant T = 12s and T = 27s where it can be seen that the flow rate is dropped to 0.2 m^3/h, this is due to the shortage of energy production.

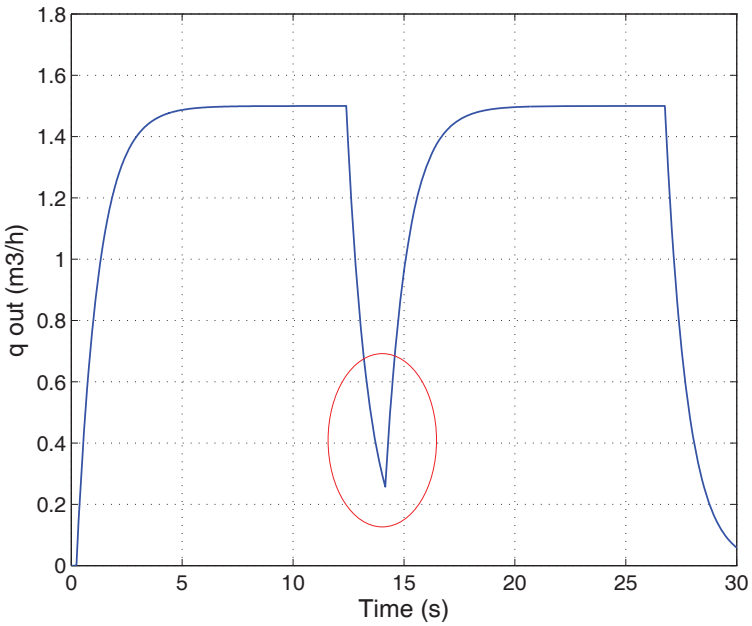

Fig. 19 Response of water pump operating.

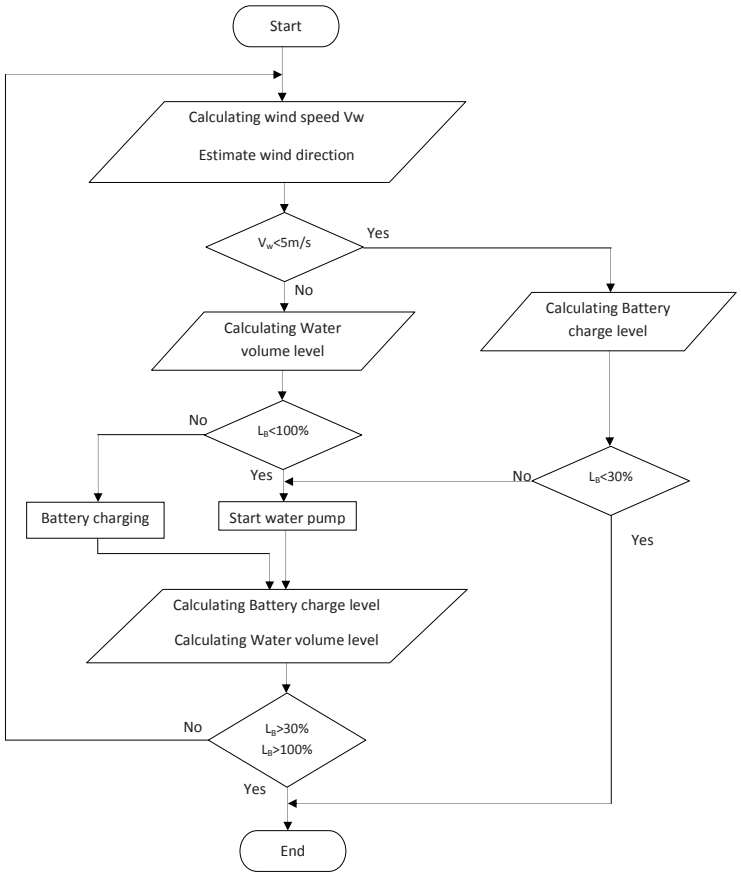

Fig. 20 Flowchart of system.

Table 3 Parameters of water pump and storage.

Parameter	*Connotation*	*Value*
Minimum voltage	$H_{\min}$	10V
maximum height	$H_{\max}$	2 m
Flow rate of pump	q_{ref}	1.5m^3/h

4.4 Controller

The controller is an electronic interface between the pump and source of energy and the tank, it can be ensured via fuzzy logic management, in this paper the system management is not taken in consideration but the flowchart was been designed to eventual work in this topic, shown in Figure 20.

5 Conclusion

This paper gives a new concept of water pumping for agricultural uses, the established system is different from the traditional process, it is a green and economic method as it uses directly a renewable source of energy, this pumping system works for different conditions in the area. Various simulations were made in the aim to choose the optimal configuration.

The achievement of this installation aims in the medium term to strengthen local capacities of isolated farming areas with rural electrification by the use of new technology away from fossil sources that can influence the environment and the quality of water. This study is motivated by the great achievements of mini wind turbines and hybrid power systems in Europe countries as we hope to get some support in this field regarding the great wind potential of Algeria.

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