ISSN 2162-5298 (Print)
ISSN 2162-5301 (Online)
DOI:10.17265/2162-5298

David Publishing Company
www.davidpublisher.com

Journal of Environmental Science and Engineering A

Volume 7, Number 1, January 2018

From Knowledge to Wisdom

Journal of Environmental Science and Engineering A

Volume 7, Number 1, January 2018 (Serial Number 67)

David Publishing Company
www.davidpublisher.com

Publication Information:
Journal of Environmental Science and Engineering A (formerly parts of Journal of Environmental Science and Engineering ISSN 1934-8932, USA) is published monthly in hard copy (ISSN 2162-5298) and online (ISSN 2162-5301) by David Publishing Company located at 616 Corporate Way, Suite 2-4876, Valley Cottage, NY 10989, USA.

Aims and Scope:
Journal of Environmental Science and Engineering A, a monthly professional academic journal, covers all sorts of researches on environmental management and assessment, environmental monitoring, atmospheric environment, aquatic environment and municipal solid waste, etc..

Manuscripts and correspondence are invited for publication. You can submit your papers via Web Submission, or E-mail to environmental@davidpublishing.org, environmental@davidpublishing.com or info@davidpublishing.com. Submission guidelines and Web Submission system are available at http://www.davidpublisher.com.

Editorial Office:
616 Corporate Way, Suite 2-4876, Valley Cottage, NY 10989, USA
Tel: 1-323-984-7526, 323-410-1082
Fax: 1-323-984-7374, 323-908-0457
E-mail: environmental@davidpublishing.org; environmental@davidpublishing.com; info@davidpublishing.com

Abstracted/Indexed in:
Googel Scholar
CAS (Chemical Abstracts Service)
Database of EBSCO, Massachusetts, USA
Chinese Database of CEPS, Airiti Inc. & OCLC
Cambridge Science Abstracts (CSA)
Ulrich's Periodicals Directory
Chinese Scientific Journals Database, VIP Corporation, Chongqing, China
Summon Serials Solutions
ProQuest

Subscription Information:
Price (per year):
Print $600, Online $480
Print and Online $800

David Publishing Company
616 Corporate Way, Suite 2-4876, Valley Cottage, NY 10989, USA
Tel: 1-323-984-7526, 323-410-1082; Fax: 1-323-984-7374, 323-908-0457
E-mail: order@davidpublishing.com
Digital Cooperative Company: www.bookan.com.cn

David Publishing Company
www.davidpublisher.com

Journal of Environmental Science and Engineering A

Volume 7, Number 1, January 2018 (Serial Number 67)

Contents

Journal of Environmental Science and Engineering A 7 (2018) 1-7
doi:10.17265/2162-5298/2018.01.001

Study on Removal of Cr(VI) from Aqueous Solution by Cross-Linked Chitosan

Xiaoyu Du[1], Yanling Deng[1], Shunsuke Sekiguchi[1], Naoto Miyamoto[2], Naoki Kano[2] and Hiroshi Imaizumi[2]

1. Graduation School of Science and Technology, Niigata University, Niigata 950-2181, Japan

2. Department of Chemistry and Chemical Engineering, Faculty of Engineering, Niigata University, Niigata 950-2181, Japan

Abstract: In this paper, the adsorbent for the removal of hexavalent Cr (Chromium) from aqueous solutions has been prepared by modifying chitosan composite with EP (Epichlorohydrin) or GA (Glutaraldehyde). The modified cross-linked chitosan was characterized by SEM (Scanning Electron Microscopy) and FT-IR (Fourier Transform Infrared Spectroscopy). Batch adsorption experiments were carried out to evaluate the adsorption of Cr(VI) by the cross-linked chitosan under different conditions. Furthermore, the sorption mechanism of Cr(VI) by the cross-linked chitosan was investigated by applying Langmuir and Freundlich isotherm equations to the data obtained. The concentration of Cr in solution was determined by ICP-MS (Inductively Coupled Plasma Mass Spectrometry). The cross-linked chitosan can be an efficient sorbent for Cr(VI).

Key words: Cross-linked chitosan, EP (Epichlorohydrin), GA (Glutaraldehyde), hexavalent Cr (Chromium), adsorption isotherms, kinetics.

1. Introduction

As is well known, the investigations on abundant levels of toxic heavy metal ions (e.g. hexavalent Cr (chromium), Cr(VI)) discharged to the environment (and its persistence in the environment) have now being received considerable attention with the development of society and the industrial economy [1]. Thus, there is need to develop novel materials having improved physicochemical properties for the removal of heavy metal ions from aqueous solution.

Chitosan is a basic polysaccharide polymer with active functional groups, and has unique physiological activity and physicochemical properties [2]. Chitosan can be easily obtained due to the widespread natural occurrence of its source which is found in the shells of crustaceans, e.g. crabs, prawns, shrimps and insects. Further, chitin is easily converted to chitosan, the desired end product, through deacetylation [3]. Therefore, chitosan has attracted increasing research interest as a potential biosorbent for the removal of heavy metal ions since it has both amine and hydroxyl groups that may serve as coordination sites to form stable chelates with various heavy metal ions [4].

Cr mainly exists in two oxidation states such as Cr(III) and Cr(VI) in natural aqueous environment. Cr(VI) has been considered more toxicity and hazardous to public health due to its mutagenic and carcinogenic properties [5]. The environmental standard of Cr(VI) is less than 0.05 mg/L, and the drainage standard is less than 0.5 mg/L. At natural aqueous environment, it may be present form of CrO_4^{2-} or $HCrO_4^-$. On the hand, Cr(III) is low toxicity, essential materials for living organisms, and the environmental standard is less than 2 mg/L. Various methods of chromium removal include filtration, chemical precipitation, adsorption, electrode position and membrane systems or even ion exchange process. Among these methods, adsorption is one of the most economically favorable and a technically easy method [6, 7]. Then authors adopted the adsorption method for the removal of Cr(VI) with the materials based on chitosan because they have high potential for adsorption of Cr [8-10].

Corresponding author: Naoki Kano, associate professor, Ph.D., research fields: environmental analysis and environmental reservation.

However, chitosan has some defects such as dissolution in acid media and notable swelling in aqueous media. Therefore, many types of chemical modification can be undertaken for offsetting the defects of chitosan. In this study, chitosan was modified by cross-linking with EP (Epichlorohydrin) or GA (glutaraldehyde).

In regard to EP cross-linked chitosan, amino groups of chitosan were not damaged during the process of cross-linking because EP are mainly associated with hydroxyl groups. In the case of GA cross-linked chitosan, the reaction of Schiff base between the aldehyde group of GA and the amido of chitosan is dominant. It is expected that cross-linked chitosan bead material with EP or GA improves the adsorption ability of Cr(VI) as well as Cu(II) and Co(II) [11, 12].

The aim of this paper is to investigate the adsorption efficiency of chitosan cross-linked with EP or GA for more practical use in the future. Experiments were conducted to determine the optimum conditions of time, pH, dosage and temperature for the adsorption. Adsorption isotherms of Cr(VI) were studied and analyzed using Langmuir and Freundlich equations, kinetics and thermodynamic analyses were also carried out. In addition, to evaluate the characteristics of the adsorbents, the surface morphology of the materials were determined by SEM (Scanning Electron Microscope), BET (Brunaeur, Emmet and Teller) method and FT-IR (Fourier Transform Infrared Spectroscopy).

2. Experimental

2.1 Materials and Reagents

Chemical reagents including chitosan was purchased from Tokyo Chemical Industry Co., Inc., acetic acid, NaOH, EP and GA were purchased from Kanto Chemical Industry Co., Inc., and all reagents used were of analytical grade. The water (> 18.2 MΩ) which was treated by an ultrapure water system (RFU 424TA, Advantech Aquarius) was employed throughout the work. Cr(VI) standard solutions used for calibration curve were prepared by diluting the standard solution (Kanto Chemical Co., Inc., 1,000 mg/L K_2CrO_7 solution). The experimental solution was prepared at 0.05-5.0 mg/L by serial dilution from the stock solution of 1,000 mg/L.

2.2 Preparation of Cross-Linked Chitosan Beads

Chitosan was stirred with the acetic acid solution 200 mL (2.0%) and added drop-wise to 100 mL of 0.5 M NaOH [13, 14].

Each cross-linked chitosan was prepared as follows. Chitosan was added to 1.0 wt% of EP, adjust the pH to 14. After keeping the mixed solution at 60 °C for 6 h, can get cross-linking with EP. Furthermore, chitosan was added to 1.0 wt% of GA, adjust the pH to 7. After keeping the mixed solution at room temperature for 24 h, can get cross-linking with GA. Chitosan cross-linked with EP or GA were described as EP and GA, respectively as below.

2.3 Characterization of These Adsorbents

Various characterization methods have been used to determine physicochemical properties of pristine and modified chitosan. The surface morphologies of these cross-linked chitosan beads were surveyed by using a SEM (Hitachi S-4300). Surface areas of these cross-linked chitosan beads before and after Cr(VI) adsorption were carried out by N_2 adsorption/desorption tests (Micromeritics TriStar 3020). Surface functional groups were identified by FT-IR spectrometer (FTIR-4200, Jasco, Japan).

2.4 Adsorption Experiments

For investigating the effects of pH, contact time, adsorbent dose, temperature and initial concentration on the adsorption of Cr(VI), the following batch adsorption experiments were conducted using cross-linked chitosan bead. The bead was thoroughly mixed with 100 dm^{-3} of containing known amount of Cr(VI) in a 200 dm^{-3} conical flask, and the

suspensions was shaken in a water bath at prescribed temperature. Adsorption experiments were performed in the pH range of 1-7, contact time from 0.5 h to 24 h, adsorbent dosage 0.10-0.50 g·dm^{-3}, temperature at 288 K-318 K and initial Cr(VI) concentration from 0.05-5.0 mg·dm^{-3}. The pH of each solution was adjusted by using 0.1 mol·dm^{-3} NaOH or HNO_3.

Following each adsorption experiment, the cross-linked chitosan bead and the above Cr(VI) solution was filtered to remove Cr(VI) that have been absorbed into the cross-linked chitosan bead, and the concentration of Cr(VI) in the filtrate was determined with an ICP-MS (Inductively Coupled Plasma Mass Spectrometry).

The adsorption capacities of Cr(VI) using modified chitosan with GA and EP at equilibrium (qe: mg·g^{-1}) was calculated using the Eq. (1):

$$q_e = \frac{(C_i - C_e)}{m} \cdot V \quad (1)$$

Where q_e is the adsorption capacities at equilibrium (mg·g^{-1}), C_i and C_e are the initial and equilibrium concentrations of Cr(VI) in a batch system respectively (mg·L^{-1}), V is the volume of the solution (L), and m is the weight of adsorbent (g).

2.5 Adsorption Isotherm Model

Adsorption isotherms are commonly used to reflect the performance of adsorbents in adsorption processes. To examine the relationship between the metal uptake (q_e) and the concentration of metal ion (C_e) at equilibrium, adsorption isotherm models are widely employed for fitting the data. To get the equilibrium data, initial concentrations of metals were varied while the adsorbent weight of each sample was kept constant. Langmuir and Freundlich isotherms model was applied to evaluate the adsorption data obtained in this study.

Langmuir model assumes monolayer adsorption onto a surface and is given by:

$$\frac{C_e}{q_e} = \frac{C_e}{q_{max}} + \frac{1}{K_L q_{max}} \quad (2)$$

Where C_e and q_e are the concentration of Cr(VI) at equilibrium (mg·L^{-1}) and the amount of adsorption of Cr(VI) at equilibrium (mg·g^{-1}) respectively, q_{max} is the maximum adsorption capacity on the surface of hybrid membrane (mg·g^{-1}), and K_L is the equilibrium adsorption constant (L·mg^{-1}). A plot of C_e/q_e versus C_e gives a straight line with slope of $1/q_{max}$, and intercept is $1/(K_L q_{max})$.

On the other hand, the linearized Freundlich model isotherm is represented by Eq. (3):

$$\log_{10} q_e = \log_{10} K_F + (1/n) \log_{10} C_e \quad (3)$$

Where K_F is the adsorption capacity, $1/n$ indicate the adsorption intensity. The plots of q_e versus C_e in log scale can be plotted to determine values of *1/n* and K_F depicting the constants of Freundlich model.

2.6 Kinetic Studies

Kinetic models have been proposed to determine the mechanism of the adsorption process which provided useful data to improve the efficiency of the adsorption and feasibility of process scale-up. In the present investigation, the mechanism of the adsorption process was studied by fitting first-order and second-order reactions to the experimental data.

The pseudo first-order model is given by Eq. (4):

$$\ln(q_e - q_t) = \ln(q_e) - k_1 t \quad (4)$$

Where q_e and q_t are the adsorption capacities of Cr(VI) using chitosan at equilibrium and time t, respectively (mol·g^{-1}), and k_1 is the rate constant of the pseudo-first-order adsorption (h^{-1}).

The linear form of the pseudo second-order rate equation is given as Eq. (5):

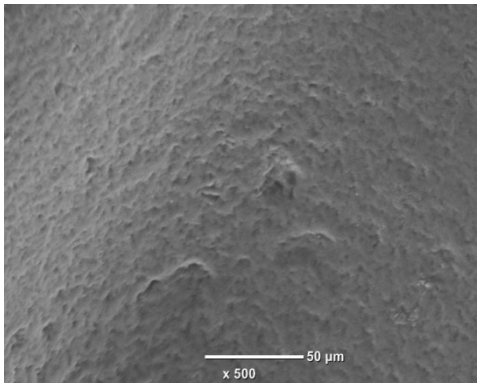
$$\frac{t}{q_t} = \frac{1}{k q_e^2} + \frac{t}{q_e} \quad (5)$$

Where q_e and q_t are the adsorption capacities of Cr(VI) using the hybrid membrane at equilibrium and time t, respectively (mol·g^{-1}), and k is the rate constant of the pseudo-second-order adsorption (g·mol^{-1}·h^{-1}).

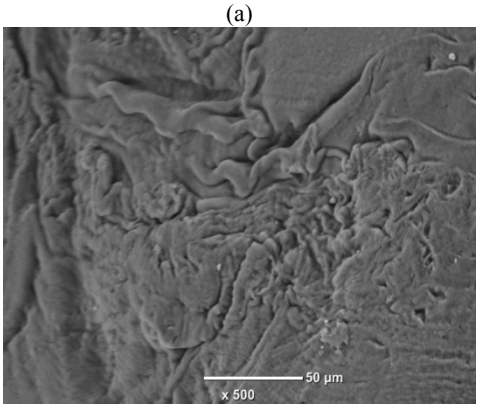
3. Results and Discussion

3.1 Characterization of Prepared Materials

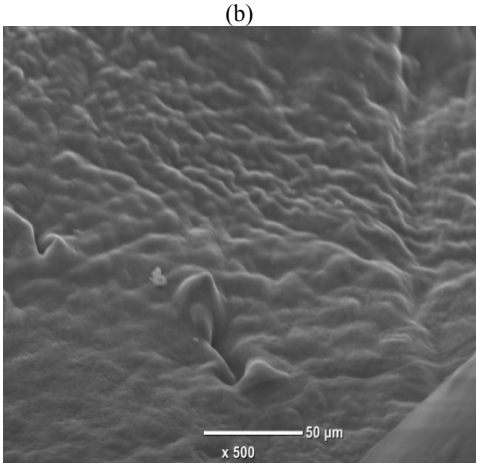
SEM pictures of the pristine and cross-linked chitosan beads are shown in Fig. 1. It can be observed that surface textures were changed. The FT-IR spectra of the pristine and the cross-linked chitosan beads are presented in Fig. 2. The broad and intense peak at 3,400 to 3,500 cm^{-1} corresponds to the -OH and -NH_2 stretching vibration of hydroxyl groups in chitosan and the cross-linked chitosan. [12, 15, 16]. The peak at 2,871 cm^{-1} is related to aliphatic methylene group. Moreover, the wide peak at 1,560 to 1,640 cm^{-1} shows the amine group which is remarkable for GA [12].



(a)



(b)



(c)

Fig. 1 SEM photomicrographs of (a) chitosan, (b) crosslinking with EP (c) crosslinking with GA.

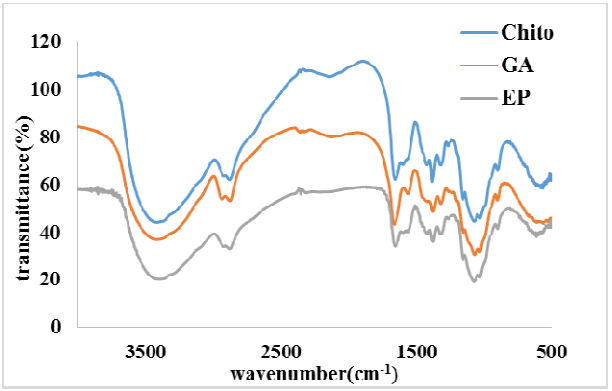


Fig. 2 FT-IR spectra of the chitosan, EP and GA.

The properties of the chitosan and the cross-linked chitosan beads were investigated by N_2 adsorption (TriStar II 3020 Micromeritics); and the pore size was calculated from adsorption average pore width (4V/A by BET) in this work is shown in Table 1. From Fig. 1 and Table 1, it is found that the surface textures were changed, and that the specific surface areas were remarkably increased after cross-linking.

3.2 Adsorption of Cr(VI) on Chitosan, EP and GA

3.2.1 Adsorption Isotherms

Langmuir and Freundlich isotherms were applied to the data obtained in this work. The linear plots of *C*e and *Q*e for these materials were presented for Langmuir and Freundlich models (Fig. 3: chitosan, Fig. 4: GA, Fig. 5: EP). The coefficients of both isotherms are shown in Table 2 (Langmuir) and Table 3 (Freundlich). From Figs. 3-5, it is also found that chitosan is more fitted to Langmuir isotherm; and that EP and GA were fitted to Frendlich isotherm as well as Langmuir isotherm compared to Chitosan. Adsorption isotherms of Cr on these materials can be generally described by Langmuir isotherm more satisfactorily. The adsorption may have occurred mainly by monolayer reaction.

Table 1 Surface areas of these cross-linked chitosan beads.

Adsorbent	Chitosan	EP	GA
BET surface area (m^2/g)	0.80	8.26	52.1

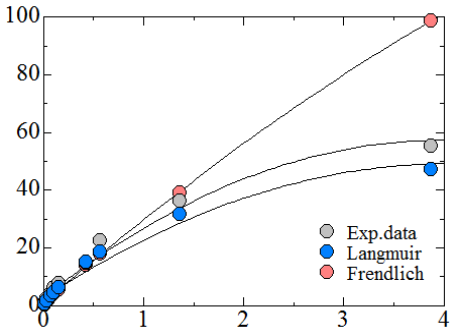


Fig. 3 Adsorption isotherm of Cr(VI) on Chitosan.

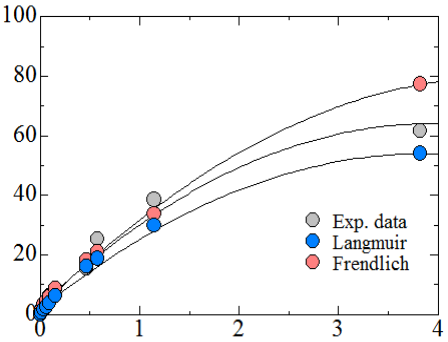


Fig. 4 Adsorption isotherm of Cr(VI) on GA.

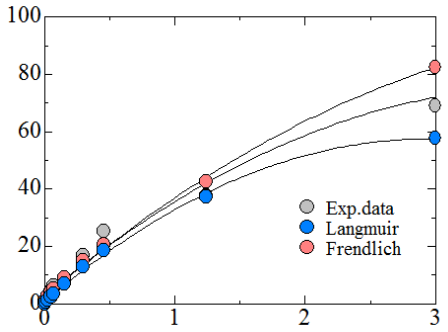


Fig. 5 Adsorption isotherm of Cr(VI) on EP.

From Tables 2 and 3, the maximum adsorption capacity of modified chitosan reached 90.9 mg/g from 49.8 mg/g by cross-linking with EP under our experimental conditions. That is to say, modified chitosan by cross-linking can be an efficient adsorbent for Cr(VI).

3.2.2 Kinetic Studies

The linear plot of q_e versus time t for Cr(VI) adsorption under the conditions (dose: 0.20 g·dm^{-3}, Cr: 500 μg·dm^{-3}, pH: 4) is shown in Figs. 6-8 (Fig. 6: chitosan, Fig. 7: GA, Fig. 8: EP). The pseudo-first and pseudo-second-order rate constant (k) and the amount of adsorbed Cr(VI) (q_e), obtained from the intercept and slope of the plot of t/q_t vs. tare listed in Tables 4 and 5 along with the regression coefficients (R^2). It implies that the adsorption kinetics based on the experimental values are in good agreement with the pseudo second-order kinetic model rather than pseudo first-order model.

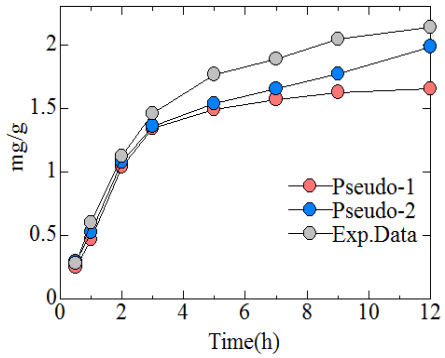


Fig. 6 Adsorption kinetics of Cr(VI) on chitosan.

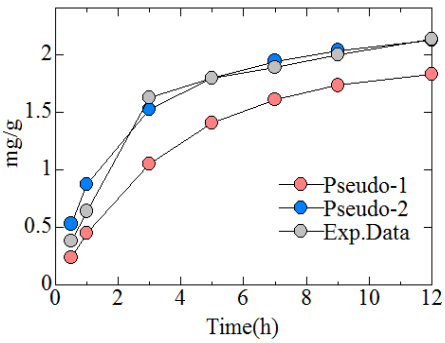


Fig. 7 Adsorption kinetics of Cr(VI) on EP.

Table 2 Langmuir isotherm parameters for Cr(VI).

	Chitosan	EP	GA
a (mg/g)	49.8	90.9	73.5
b (L/mg)	2.87	0.558	0.594
R_L	0.0337	0.152	0.144
R^2	0.979	0.989	0.997

Table 3 Frendlich isotherm parameters for Cr(VI).

	Chitosan	EP	GA
K_F	26.4	36.2	30.8
$1/n$	0.841	0.721	0.685
R^2	0.941	0.980	0.977

Table 4 Pseudo-first-order model kinetic parameters.

	Chitosan	EP	GA
K_1 (h^{-1})	0.330	0.267	0.192
q_e $(mg/g)_{exp}$	2.23	2.21	2.29
q_e $(mg/g)_{cal}$	1.66	1.90	2.31
R^2	0.980	0.973	0.943

Table 5 Pseudo-second-order model kinetic parameters.

	Chitosan	EP	GA
K_2 (g/mg h)	0.135	0.226	0.0975
q_e $(mg/g)_{exp}$	2.23	2.21	2.29
q_e $(mg/g)_{cal}$	2.26	2.44	2.72
R^2	0.983	0.989	0.935

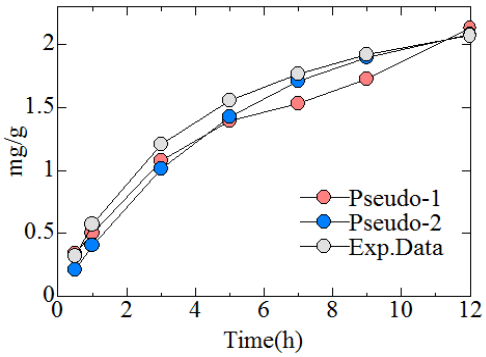


Fig. 8 Adsorption kinetics of Cr(VI) on GA.

4. Conclusions

The maximum adsorption capacity of modified chitosan reached 90.9 mg/g from 49.8 mg/g by cross-linking with EP under the experimental conditions. Adsorption isotherms of Cr on the modified chitosan can be generally described by Langmuir isotherm more satisfactorily. The adsorption may have occurred mainly by monolayer reaction. The rates of adsorption using the modified chitosan for the removal of Cr were found to conform to pseudo-second order kinetics. Modified chitosan by cross-linking can be an efficient adsorbent for Cr.

Acknowledgements

The present work was partially supported by a Grant-in-Aid for Scientific Research (Research Program (C), No. 16K00599) of the Japan Society for the Promotion of Science. This research was also supported by a fund for the promotion of Niigata University KAAB Projects from the Ministry of Education, Culture, Sports, Science and Technology, Japan.

The authors are also grateful to Mr. M. Ohizumi of Office for Environment and Safety in Niigata University, Dr. M. Teraguchi, Mr. T. Hatamachi, Mr. T. Nomoto and Prof. T. Tanaka of Fac. of Eng. in Niigata University for permitting the use of ICP-MS, FT-IR, Surface Area Analyzer and SEM for giving helpful advice in measurement.

References

[1] Laus, R., Costa, T. G., Szpoganicz, B., and Fávere V. T. 2010. "Adsorption and Desorption of Cu(II), Cd(II) and Pb(II) Ions Using Chitosancrosslinked with Epichlorohydrin-triphosphate as the Adsorbent." *J. J. Hazard Matter* 183 (1-3): 233-41.

[2] Aydin, Y. A., and Aksoy, N. D. 2009. "Adsorption of Chromium on Chitosan: Optimization, Kinetics and Thermodynamic." *Chem. Eng. J.* 151 (1-3): 188-94.

[3] Li, X., Zhou, H., Wu, W., Wei, S., Xu, Y., and Kuang, Y. 2015. "Studies of Heavy Metal Ion on Chitosan/Sulfydryl-functionalized Graphene Oxide Composites." *J. Colloid. Interf. Sci.* 448: 389-97.

[4] Kołodynska, D. 2011. "Chitosan as an Effective Low-cost Sorbent of Heavy Metal Complexes with the Polyaspartic Acid." *Chem. Eng. J.* 173 (2): 520-9.

[5] Baroni, P., Vieira, R. S., Meneghetti, E., da Silva, M., and Beppu, M. M. 2008. "Evaluation of Batch Adsorption of Chromium Ions on Natural and Crosslinked Chitosan Membranes." *J. J. Hazard Matter* 152 (3): 1155-63.

[6] Huang, G., Zhang, H., Shi, J. X., and Langrish, T. S. G. 2009. "Adsorption of Chromium(VI) from Aqueous Solutions Using Cross-Linked Magnetic Chitosan Beads." *J. Ind. Eng. Chem. Res.* 48 (5): 2646-51.

[7] Ngah, W. S., Ghani, S. A., and Kamari, A. 2005. "Adsorption Behaviour of Fe(II) and Fe(III) Ions in Aqueous Solution on Chitosan and Cross-linked Chitosan Beads." *Bioresour. Technol.* 96 (4): 443-50.

[8] Modrzejewska, Z., Sujka, W., Dorabialska, M., and Zarzycki, R. 2006. "Adsorption of Cr(VI) on Cross-linked Chitosan Beads." *Separat. Sci. Technol.* 41 (1): 111-22.

[9] Jaros, K., Kaminski, W., Albinska, J., and Nowak, U. 2005. "Removal of Heavy Metal Ions: Copper, Zinc and Chromium from Water on Chitosan Beads." *Environ. Prot. Eng.* 31 (3-4): 153-62.

[10] Zarzycki, R., Sujka, W., Dorabialska, M., and Modrzejewska, Z. 2002. "Adsorption of Cr(VI) on

Chitosan Beads." *Chem. Inz. Ekol.* 9: 1561-70.

[11] Ngah, W. S., Endud, C. S., and Mayanar, R. 2002. "Removal of Copper(II) Ions from Aqueous Solution onto Chitosan and Cross-linked Chitosan Beads." *React. Funct. Polym.* 50 (2): 181-90.

[12] Cestari, A. R., Vieira, E. F. S., Oliveira, I. A., and Bruns, R. E. 2007. "The Removal of Cu(II) and Co(II) from Aqueous Solutions Using Cross-linked Chitosan-evaluation by the Factorial Design Methodology." *J. Hazard Matter* 143 (1-2): 8-16.

[13] Ngah, W. S. W., Teong, L. C., and Hanafiah, M. A. K. M. 2011. "Adsorption of Dyes and Heavy Metal Ions by Chitosan Composites." *A Review Carbohydr. Polym.* 83 (4): 1446-56.

[14] Sushanta, D., Arjun, M., and Kriveshini, P. 2014. "Magnetic Chitosa-GO Nanocomposite: Synthesis, Characterization and Batch Adsorbed Design for Cr(VI) Removal." *J. Environ. Chem. Eng.* 2 (2): 963-73.

[15] Motawie, A. M., Mahmoud, K. F., El-Sawy, A. A., Kamal, H. M., Hefni, H., and Ibrahiem, H. A. 2014. "Preparation of Chitosan from the Shrimp Shells and Its Application for Pre-concentration of Uranium after Cross-linking with Epichlorohydrin." *J. Egyptian Journal of Petroleum* 23 (2): 221-8.

[16] Ngah, W. S., Endud, C. S., and Mayanar, R. 2002. "Removal of Copper(II) Ions from Aqueous Solution onto Chitosan and Cross-linked Chitosan Beads." *React. Funct. Polym.* 50 (2): 181-90.

Journal of Environmental Science and Engineering A 7 (2018) 8-21
doi:10.17265/2162-5298/2018.01.002

A Decision Support System Web—Application for the Management of Forest Road Network

Apostolos Kantartzis[1] and Chrisovalantis Malesios[2]

1. Department of Forestry and Management of the Environment and Natural Resources, Democritus University of Thrace, Orestiada 68200, Greece

2. Department of Agricultural Development, Democritus University of Thrace, Orestiada 68200, Greece

Abstract: The present study contributes to the development of an online FRMP (Forest Road Management Platform) that aims to assist in the management of forest road network in a holistic way. This is achieved by the proposed methodology which serves as a database using geoprocessing and geospatial technologies for the handling, and the identification of critical issues in the infrastructure of forest road networks, visualization of forest roads, and the optimization of the management of the forest road network by proposing alternative strategies. In this paper, the development of the decision making web-tool, and presented examples to demonstrate effectively its application and resulting advantages are described. The developed web-application may provide assistance to various forest organizations in the management of forest road networks and associated problems in an effective and sustainable way.

Key words: Forest road network, web-application, management of forest roads, sustainable forest management, GIS (Geographic Information Systems).

1. Introduction

The implementation of planning in the context of road network maintenance activities appears to be a necessity which significantly affects the policy of technical interventions at national, regional and local levels in each country. Until recently, each maintenance policy was distinguished from interventions whose main objective was to repair major operational malfunctions on low-quality pavements in terms of qualitative characteristics. However, contemporary perceptions on this issue go into a more in-depth analysis of the problem and propose a systematic information policy that is structured around three main axes: diagnosis-forecast-planning.

Nowadays, the need for an even more integrated management approach of woodlands as well as the flexibility that a full road network offers against the prevention of risk of forest fires have led forest authorities to the completion of the opening of many woodlands. Smooth access to all points of the forest road network throughout the year is a challenge as well as its proper management and organization for its maintenance. Building a unified database that will function as a platform for development within a forestry area can be considered to be the cornerstone for the generation of a developmental plan. Such a plan will include the registration and production of an electronic database that consists of the basic elements and of the main characteristics of the forest road network and the forest techniques applied so far.

Contradictory situations often arise such as addressing and managing forest road network problems that their full dimension is unknown. Thus, it is evident that part of the solution to a problem is to record the knowledge of the quantity and quality of its data and then make decisions to adequately deal with it.

Forestry works are basic infrastructure projects for the development of the mountainous and national economy in general, and thus it is needed to address them in conjunction with other problems associated

Corresponding author: Chrisovalantis Malesios, Ph.D., Marie-Curie Research Fellow, main research fields: applied statistics, environment and agriculture.

with the protection and preservation of forest wealth.

The mountain inhabitants' economy is based on forests, which constitute a valuable resource. The need for further exploitation is evident, both for the improvement of the living standards of forestry and suburban population, as well as for the greatest possible tourist, aesthetic, hygienic and above all, their protective performance. However, in order to achieve and implement any development action in the mountainous area and especially in the forest areas, it is important to make necessary infrastructure works and in particular to develop the necessary network of forest roads.

Forest roads are an essential yet costly part of forest management, hence optimization methods are significant tools in the planning of road systems [1, 2]. Forest road planning plays an important role in forest management and logging practices [3]. The importance of forest roads is stressed in various studies in the literature for a variety of reasons such as wood production and ecotourism [3], sustainability and environmental impact on forests [4].

On the other hand, forests roads are often considered to be controversial investments due to the fact that they may trigger or increase soil erosion [5, 6], habitat fragmentation [7], or illegal logging [8]. Hence, the planning processes can become quite complex [9], because all these negative side-effects may grow with the density of the forest road network.

Thus, it is evident that forest road network planning plays a crucial role in fulfilling the goals of sustainable forest management. There are research studies on forest road planning [10-12].

Forest road network planning and maintenance therefore require the development of rational approaches to collecting and evaluating the technical, circulatory, economic data of each problem and to come up with concrete proposals for the required interventions taking into account all technological developments in the field of road construction. Towards these approaches, Dragoi, M., et al. [13] utilized benefit, cost and risk analysis on extending the forest roads network using a case study in Romania. It is evident from the above presentations of forest road management applications, that forest road network planning and management plays a crucial role in fulfilling the goals of a sustainable forest management system [10]. To the best of the authors' knowledge, there are no globally-adoptable tools and platforms for the decision making that may assist in the management of forest road network in a holistic way.

The aim of the current paper, is the presentation of an online FRMP (Forest Road Management Platform) that may assist in the management of forest road network in a unified way. The proposed computer application is aiming to adequately identify and handle potential critical issues in the infrastructure of forest road networks, visualization of forest roads, and the optimization of the management of the forest road network.

There are many applications that the proposed decision making web-tool can be utilized for. For example, the developed tool could be used to optimize the operation of the forest offices in relation to the forest road network (these may include marking trees for felling, transit of truck drivers to pick up timber and moving workers for logging), or members of other public services moving to a forest road network, such as directorate of coordination and supervision of forests or fire department, forest guard/game guard body or forest officers. Additionally, it can be exploited by individuals who visit and wish to approach remote parts of a forest, e.g. tourists, hunters.

It is believed that a modern view on this issue will offer a deeper analysis of the problem and will help suggesting a policy of maintenance on a systematic basis that will be organized around the already mentioned three pillars of diagnosis-forecast-programming [14].

The fully-integrated systems of maintenance usually consist of mathematical models that are equivalent to the three pillars mentioned above and they are used to

manage and assess the data of a problem, from technical, circulatory and financial perspective, leading to specific solutions necessary for the interventions that have to be made defining at the same time the time needed for the execution, the size, type and cost of the operations. Such a system was applied in a specific area of investigation, i.e. the forest of Koupa, Thessaloniki, Greece.

Specifically, an integrated system consisting of various open source technologies and code for managing, in a (cost-)effective way, forest road networks has been designed.

Some of these technologies, developed in the current study are:

- An Online Forest Management Platform;
- An SQL Server to maintain and disseminate the data;
- A MapServer for serving of the spatial data.

The rest of the paper is organized as follows. Section 2 describes in detail the development of the proposed decision making web-tool for the management of forest road network system. Section 3 illustrates the applicability and advantages of the proposed methodology through the use of real-data examples. Finally, section 4 concludes with the main objectives and proposals of the current research.

2. Material and Methods

The systematic approach to forest road management and maintenance stems from the need for precise information on the actual situation of the road and road construction problems in order to predict their future situation and to compare and select between different route alternatives [15]. In this section, a detailed description of the development and application of the web-based forest road management tool that includes the recording and creation of a digital database on the characteristics of the forest road network and its forestry projects and proposes practical and reliable solutions will be presented.

The main objective is the exploitation of all data resulting from the use of these modern technologies (Orthophotos, orthophotographic maps, digital terrain models, land use cartographic polygons etc.) for the development of different forest applications using GISs (Geographic Information Systems).

The main feature of GIS is that they allow the connection between qualitative and descriptive features with spatial information. They are not simply a means of producing maps, charts or lists of qualitative features, but a new integrated technology necessary for the analysis and study of space and a decision making tool relating to the environment and man [16]. GISs were used using the national geographic road database in Sweden to take account of various factors (e.g. logging, spinning, costs, accessibility, etc.) to provide efficient planning for improving the forest road network to ensure a smooth supply of forest products to the corresponding forest industries [16]. Gumus, S., et al. [17] use GIS to assess the forest road network environmentally by looking at figures from various environmental indicators.

The structure of the application proposed in the current study, allows one to combine visual, geospatial data together with descriptors so that the user of the application can have the best possible understanding of the forest road network problem that has been reported. Thus, in overall, the proposed application can include a description of the problem, the location of the problem illustrated on a forest map in order to be able to estimate with the help of the program, the severity, cost and the best suggested solution for the problem that has been reported.

2.1 Architecture Utilized for the Creation of the Web-based FRMP Tool

In order to create this web application for internal usage, the MVC (Model-View-Controller) architecture has been chosen. Specifically, the ASP.NET by Microsoft with the “entity” framework is used. The MVC architectural pattern segregates the application into three main components: (a) the model, (b) the view,

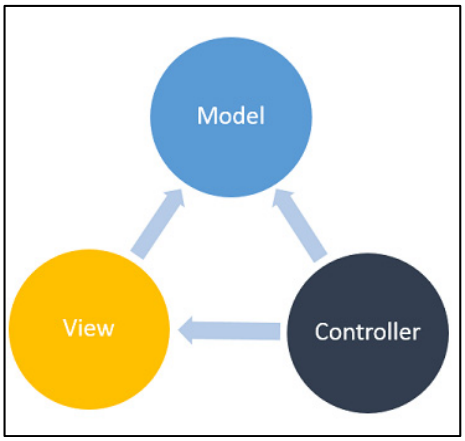


Fig. 1 The basic MVC design pattern.

and (c) the controller (see Fig. 1 for a visual explanation of the basic MVC design pattern).

The ASP.NET MVC framework provides an alternative to the ASP.NET Web Forms pattern for creating Web applications. The ASP.NET MVC framework is a lightweight, highly testable presentation framework that (as with Web Forms-based applications) is integrated with existing ASP.NET features, such as master pages and membership-based authentication. The MVC framework is defined in the System.Web.Mvc assembly.

MVC is a standard design pattern. The MVC framework utilized for the proposed web tool includes the following components:

• Models: Model objects are the parts of the application that implement the logic for the application's data domain. Often, model objects retrieve and store model state in a database. For example, a Product object might retrieve information from a database, operate on it, and then write updated information back to a Products table in a SQL Server database.

• Views: Views are the components that display the FRMP web application's UI (User Interface). This UI is created from the model data. An example would be an edit view of a Products table that displays text boxes, drop-down lists, and check boxes based on the current state of a Product object.

• Controllers: Controllers are the components that handle user interaction for the platform, work with the model, and ultimately select a view to render that displays UI. In the proposed MVC application, the view only displays information; the controller handles and responds to user input and interaction. For example, the controller handles query-string values, and passes these values to the model, which in turn might use these values to query the database.

The above described MVC pattern assists in creating applications that separate the different aspects of the application (input logic, business logic and UI logic), while providing a loose coupling between these elements. The pattern specifies where each type of logic should be located in the application. The UI logic belongs in the view, input logic belongs in the controller and business logic belongs in the model. This separation helps managing complexity for building the web-based FRMP application, since it enables focusing on one aspect of the implementation at a time. For example, one may focus on the view without depending on the business logic.

There are certain advantages for the utilization of the MVC for the development of the FRMP Web-Based Application. First, the ASP.NET MVC framework makes it easier to manage complexity by dividing an application into the "model", the "view", and the "controller". Second, it does not use view state or server-based forms. This makes the MVC framework ideal for developers who want full control over the behavior of an application. It additionally uses a Front Controller pattern that processes Web application requests through a single controller. This enables one to design an application that supports a rich routing infrastructure. MVC also provides better support for TDD (Test-driven Development).

Finally, it performs well for web applications that are supported by large teams of developers and for web designers who need a high degree of control over the application behavior.

2.2 Description of the FRMP Platform

Hence, an internal-use application is designed, based

on the previously described ASP.NET MVC framework, in the form of a web application consisting of two main parts. The first section describes the production of a land registry database that includes the process of registration and production of an integrated database that consists of road network data, such as the recording and classification of forest works and forest roads problems and their subsequent taxonomy in terms of the degree of their accessibility. In particular, the first section involves the registration and input of list of data relating to the potential problems of the forest road network of interest, such as collapses of rocks, landslides, ditch blockings, erosions, mobility of a road or a specific section of a road. The main benefit is that the existence of such a database can be used both for the better and the more objective and economical management and settlement of the forest roads. With the spatial information provided, there is a more prudent picture of the state of the forest road network of each forest cluster so that practical and reliable solutions can be adequately proposed and implemented.

The primary goal is to become as flexible and efficient as possible in the shortest possible time. By the electronic recording and creation of this database, the scarce financial resources that one may have, can be prioritized and directed.

At a second stage (second part), the user (e.g. an administrator) of the web-application can observe the list of problems and reports, in combination with the forest map, so that the former can be effectively controlled. Hence, the administrator can choose one or multiple problems or reports massively to mark them as resolved, to make assignments for repairs and can calculate costs according to distance and type of the specific problem. More specifically, the collected data are stored into an SQL server. Subsequently it is desirable to be able to display them in a compact format e.g. through a browser to minimize the workload. It is desirable to have an interface which helps the "recorder" of the database to register a problem as fast as possible without making it difficult for the user. In addition, serve spatial data alongside the info will be served in order to make the user understand the location of the problem with simple directions from the caller (see flowchart in Appendix for a step by step description of the stages of FRMP application).

In order to store the data and to directly distribute it to the users of the application, a database that is 100% compatible with the automated system of the entity framework has been chosen. Hence, the database is an SQL Server 2014 Express edition.

For serving geo-spatial data, the MapServer environment has been selected. MapServer is an open source development environment for building spatially enabled internet applications. It can run as a CGI program or via MapScript which supports several programming languages (using SWIG (Simplified Wrapper and Interface Generator)). MapServer was developed by the University of Minnesota—thus, it is often and more specifically referred as "UMN (University of Minnesota) MapServer", to distinguish it from commercial "map server". MapServer was originally developed with support from NASA, which needed a way to make its satellite imagery available to the public. The basic source code for the replication of the web application is available upon request by the corresponding author.

Next, for a description of these two parts, a usage scenario will be presented. Suppose that the application is installed on a central server of a forestry service. Then it is divided into two main categories.

For the purposes of this scenario, it is assumed that a user of the application is someone who has the post of a phone operator in a forestry office and (s)he is called the "CCO (Call Center Operator)". Subsequently, a second user will be the manager of the application, called the "AM (Application Manager) ". When the forestry office receives a call for reporting of a problem, at some particular geographical location of its forest road network, or a problem with a technical project, such as a ditch, then the CCO uses the application to

record the problem through a simple menu (1st stage).

Next (2nd stage), the AM has the ability to view the complete list of problems and reports at the same time visually, for instance through a forest map so that the entire forest road network can be controlled. Specifically, the AM can choose one or more of the problems or reports, to mark them as resolved, assigning repairs, and being able to calculate costs according to distance and type of problem.

To illustrate the Forest Roads Management System in more detail, in the following, a hypothetical scenario from a typical forest area located in Northern Greece is described. Fig. 2 shows the main screen of the application tool, for the "CCO" (1st stage).

With this simple interface, the ability to the user (e.g. the AM or CCO) to choose a part of the road to view in detail is provided. Suppose that one wants to concentrate on a specific part of the forest road network of the region of interest (Fig. 3). Upon choosing the part of the road network, the "CCO" person chooses a part and then has three options: "Details", "Edit" and "Report a new problem" (Fig. 4).

If the "CCO" wants to register a new problem, he/she chooses the "report a new problem" tab. Then, (s)he logs the problem to the problems table by clicking on the map at the specific point or part of the road where the problem occurs. Subsequently, one chooses the type of the problem, types some description and presses "complete". By doing so, the system registers the current time and date and the specific user that reported the problem.

By clicking on the "details" button, the CCO can get and accordingly edit all relative information of the specific part of the forest road in a simple format.

Next, from either the main menu or the "details" menu, the CCO can choose to edit the current information and insert updated information, through the "edit" tab menu of the web application (Fig. 5).

After editing is completed, the user can return to the main initial screen of the web-application. If the user chooses to report a new problem, (s)he can see a report problem form like the one presented in Fig. 6, titled as the "report problem" tab.

By simply filling the associated tabs with all the relative information, the register can subsequently save the created report. Later the "AM" can readily view the lists comprising of all problems associated with the forest road network of interest. Fig. 7 displays an overall report list comprising of all problems and issues in the particular part of the forest road of interest. From

Fig. 2 Forest road map as shown via the web application tool.

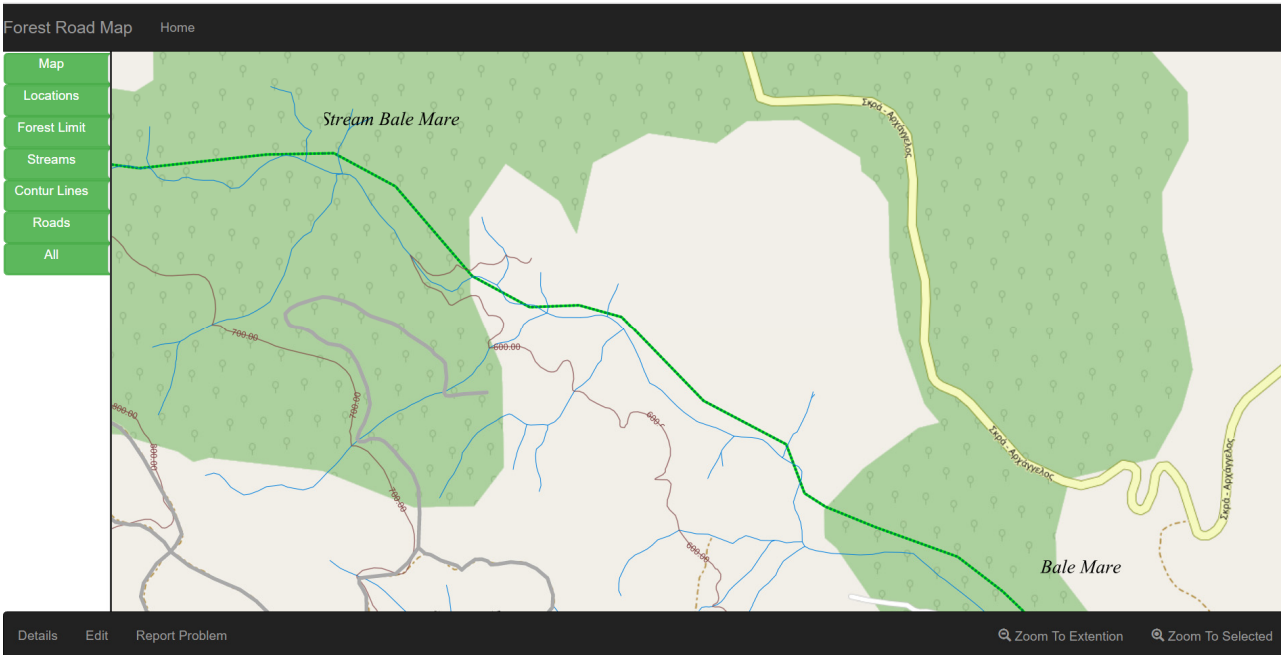


Fig. 3 Selection of a specific part of the forest road map.

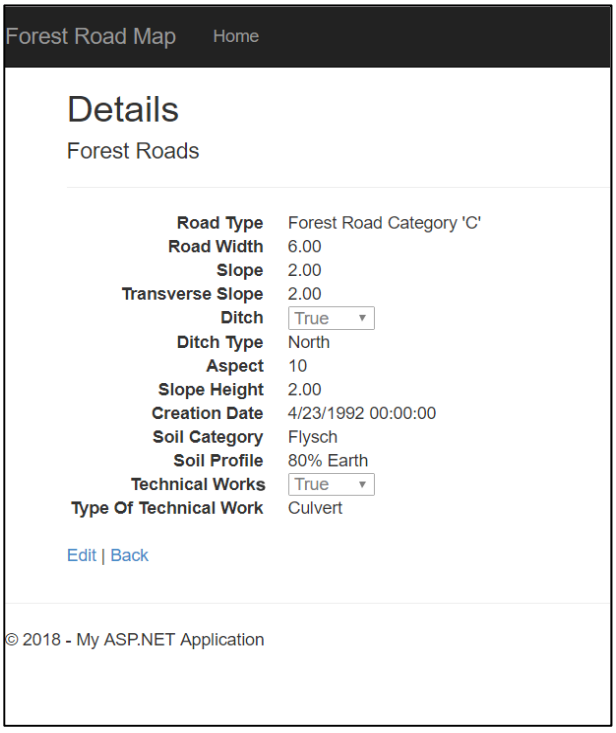


Fig. 4 The "details" tab of the web application tool.

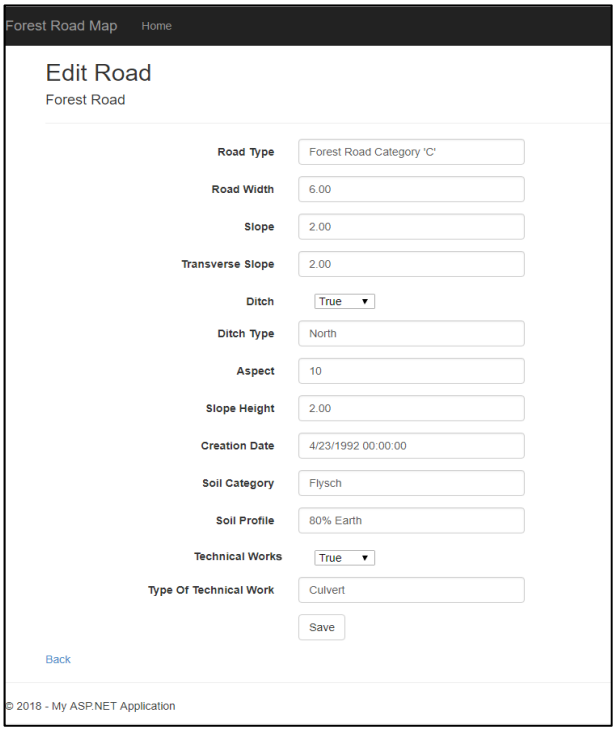


Fig. 5 The "edit road" tab menu of the web application.

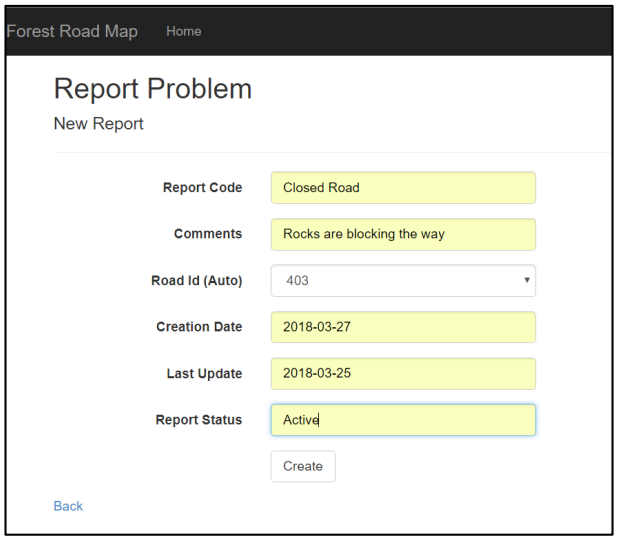


Fig. 6 The "report problem" tab menu of the web application.

this menu, the AM can perform a variety of actions, such as edit, assign or close any open "Report list" in order to have the availability of the state of the forest roads always up to date. In particular, when the AM opens the main page of the web application and clicks on the part of the forest road network that is of interest, a menu appears with all the relevant information available, i.e. the road status (open/closed) and reported problems. Additional information includes road info such as: slope, shape, length etc. of the specific part of the forest road network (An alternative approach to the above described scenario is the option to give that access to the public so anyone can do exactly the same from his device of choice).

When there is need for repairing the problematic parts of the forest road network, the commanding officer or the responsible employee of the forest office opens the commanding menu. (S)he chooses the types of problems (s)he wants to solve or the exact spot that needs to be repaired. Commanding officer checks all the info about the damage or problem and can calculates the costs with more accuracy. When the repair is complete, one may mark the road as open again.

3. Results and Discussion

In the current section, an illustrative example of the utilization and the implementation of the proposed forest road network management web-tool is presented.

3.1 Study Area

The research area, namely the Koupa forest, is located in the Kilkis prefecture, of the Region of Central Macedonia, Northern Greece. Fig. 8 shows the visual presentation of the forest location at the geographical and political partition of the country, compared with the existing transport network.

The forest occupies the northeastern slopes of Mount Paiko. The area enclosed within the boundaries, using GIS map info was found to be 27,521.9 acres. The main forest species constituting the high forest are the oaks, i.e. species that can produce technical wood. The forest of Koupa presents a varied geomorphological relief. Its altitude varies between 380-1,540 m. There are many ridges across the forest in any direction, creating a variety of environments and orientations. Also, corresponding streams and tremors are often met in this forest area.

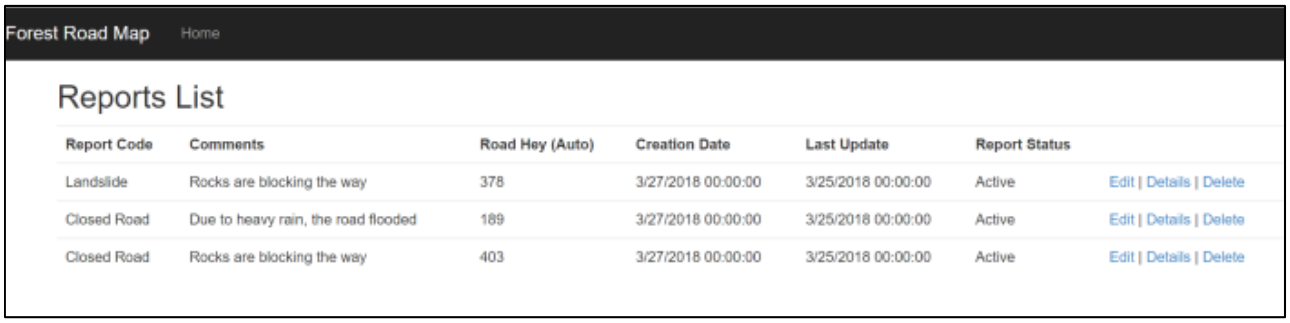


Fig. 7 The overall "Report list" tab menu of the web application.

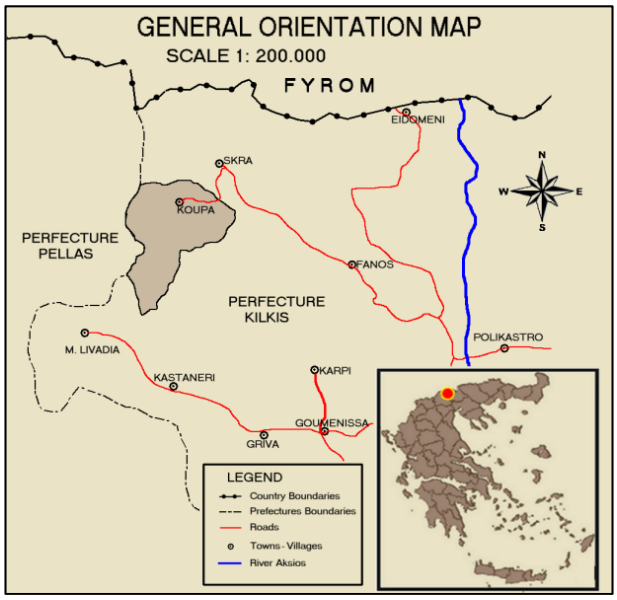


Fig. 8 Map of the study area.

Note that as a study area, a typical forestry area has been used, which due to certain characteristics is suitable for the current implementation. The total area covers 2,750 ha and the total length of the road network is 66 km. The existing road density is 24 m/ha, so a fully developed forest area with a rich forest road network with several intersections and alternate routes is utilized.

If one observes the climatic conditions of the particular forest area, it can be found: the month of June has the lowest rainfall height of 25.3 millimeters. During winter (January to March), the rainfall amounts to 270.5 millimeters and the average monthly is 90.16 millimeters. During the blooming period from April to September, rainfall amounts to 381.2 millimeters and the average monthly is 63.53 millimeters. During the dry-heat period (June to September), the rainfall amounts to 205.5 millimeters and the average monthly is 51.37 millimeters.

The climatic environment that is observed is between the continental and the trans-European climate. The above is also evidenced by the fact that the beech appears in the forest at the altitude of 500 meters, indicating that the climatic conditions are favorable for its development. Snowfall is at a high level, while the northern exposure of most of the forest can lead to significant forest road problems.

Taking into account the climate of the area in conjunction with the horticultural formation and the fact that most of the forest road network is a C-class forest roads, it is understood that after each winter period most of the forest road network needs important maintenance, rendering this forest area most suitable for the present illustration.

3.2 Implementation of FRMP through Case Studies Scenarios

In the current section, an implementation case scenario of the web-tool in order to show-case the strengths and benefits of the use of the FRMS program is presented.

Hence, a typical scenario of a person traveling to the forest of Koupa from say a point A to point F, covering a total distance of 7.769 km, by using the shortest destination path, according to the road map (Fig. 9) is analyzed. Then, it is further assumed that this person will be the driver of a truck carrying logging. Typically, the driver sees the map of the forest road network, chooses a path, fills the truck with gas and calculates the time he needs to load wood and transport it to the desired destination (Fig. 9 shows the shortest route, highlighted with the red line). This will be referred to as the A scenario.

The corresponding estimated time t for covering this distance is calculated based on the Greek fire service's official information, according to which a 10-tonne vehicle, moves at a speed of 30 km per hour at a forestry road [18]. For the example, half of that speed as the truck of the example can reach up to 30 tons of load and typically cannot approach the average speeds of fire brigade vehicles has been assumed. Hence, for the purposes of the present analysis, it is assumed that a truck of 10-tonne covers the distance of 1 km in a typical forest road in approximately 4.3 minutes.

Next, suppose that the specific forest road network at the current time has a construction problem in the form

of an obstacle, specifically at a certain point, the accessibility is not possible (Fig. 10).

Without the use of the FRMS application, the driver chooses to follow a different route, after he confronts with the problem, hence essentially needs to turn back and choose an alternative route (this situation will be referred to as the B scenario). Then, the standard distance, time and costs will change depending on the next shortest path. Note also, that the alternative route may also end up with another problem which the driver is not aware of at the current time. However, for simplicity, assume that the alternative route does not suffer from additional problems. For the specific example, the driver will have to drive back 5,348 km to the nearest crossroads in order to take a longer route and drive for 6,107 additional kilometers.

Fig. 9 Shortest destination path according to scenario A.

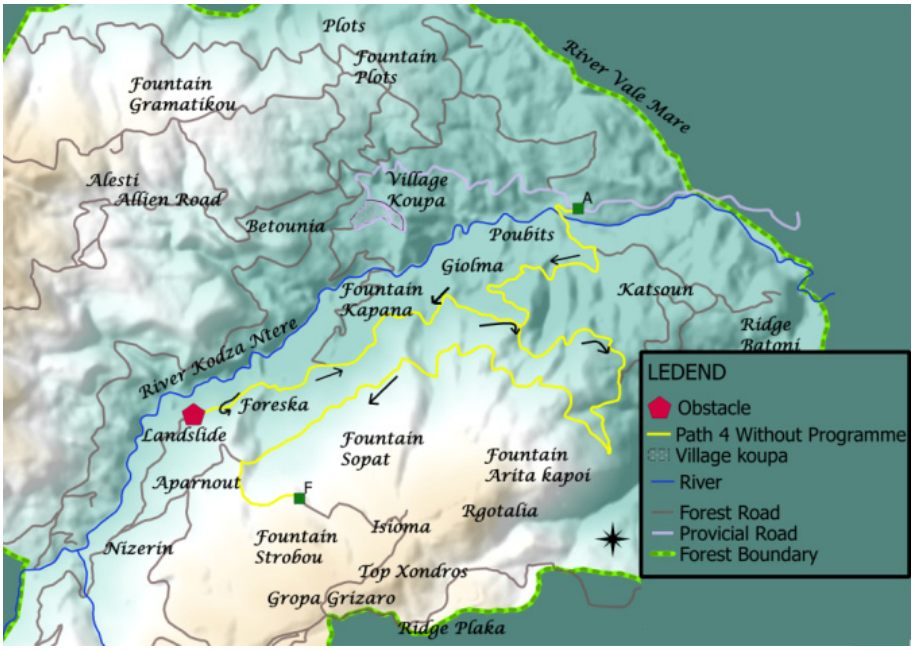


Fig. 10 Destination path followed according to scenario B.

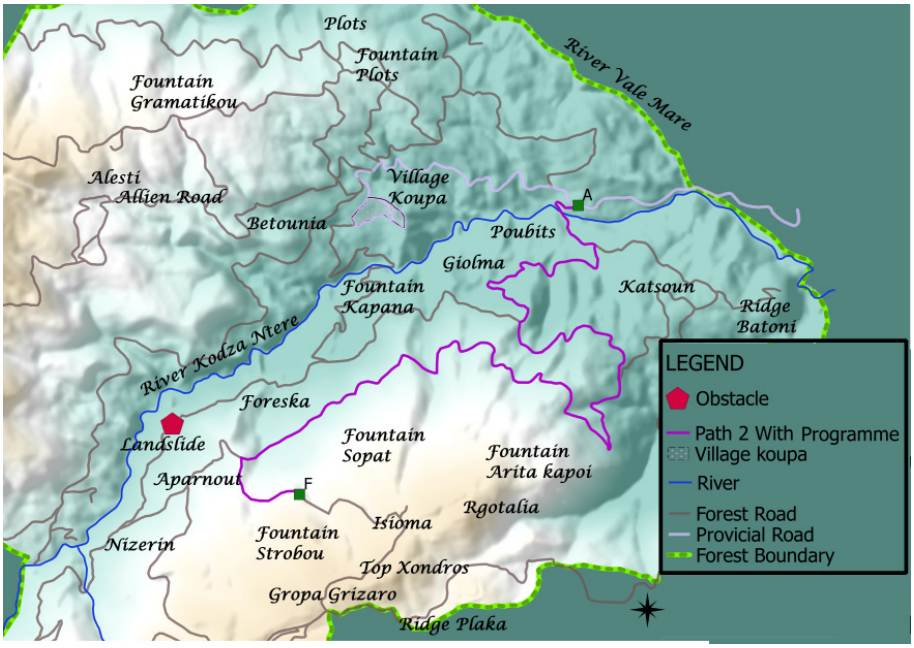


Fig. 11 Destination path followed according to scenario C.

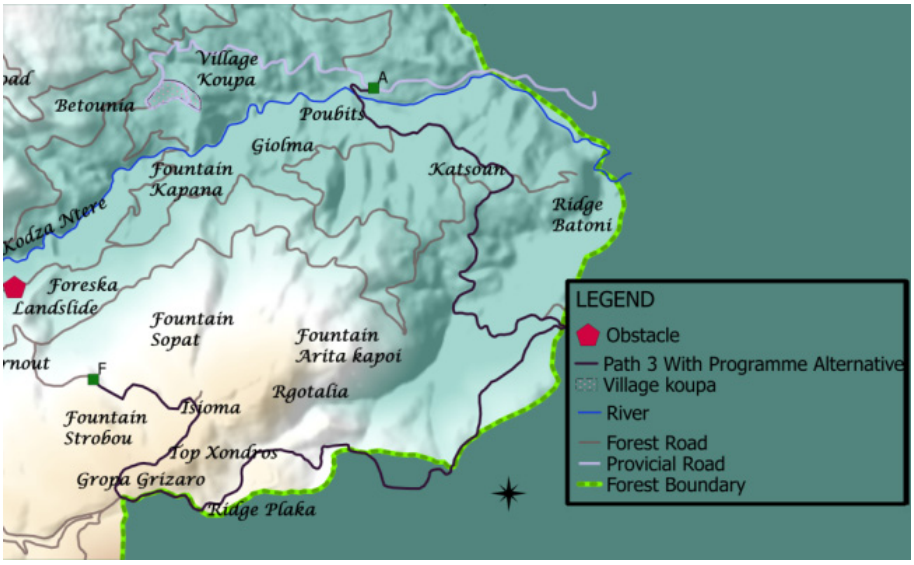


Fig. 12 Destination path followed according to scenario D.

Next, the two additional alternative scenarios that the driver can implement by using the FRMS decision-making program can be examined (Scenarios C and D). At the start of the travelling schedule, the driver checks the up-to-date web tool, hence will be informed on the road obstacle at the specific part of the route, and subsequently decide which is the shortest path. In the current situation, the program will inform the driver about the problem and suggest various alternative routes (Figs. 11 and 12 show two alternative routes as suggested by the FRMS). Also, the Forest Office would be able to provide more accurate info to the driver. Note also the possibility for the driver to check the status of the forest road network at a real-time upon the availability of internet access.

The basic parameters of the four alternative scenarios (i.e. distance traveled and time consumed) are comparatively shown in Tables 1 and 2 for the alternative scenarios utilized. Specifically, Table 1 shows the values of the calculated parameters, whereas

Table 1 Calculated parameters' values for the alternative scenarios.

	Parameters	
	Distance traveled (*d*)	Time (*t*)
Scenario A	7,769 km	33.29 min
Scenario B	13,603 km	58.29 min
Scenario C	8,256 km	35.38 min
Scenario D	9,775 km	41.89 min

Table 2 Calculated percentage of change in the parameters (with reference to scenario A).

	% of change in parameters in relation to scenario A	
	% of change in *d*	% of change in *t*
Scenario B	75.09%	75.10%
Scenario C	6.27%	6.28%
Scenario D	25.82%	25.83%

Table 2 presents the corresponding percentage of change of the parameters, with respect to the shortest available route that would have been followed by the driver in case of no road network issues (scenario A).

It is evident from the inspection of the results of Tables 1 and 2 that the possible utilization of FRMS would substantially reduce the total distance and time covered by the truck driver of the hypothetical scenario and corresponding costs, in case of a potential problem in the forest road network of the region. It is seen that without the assistance of FRMS the driver could potentially double the total distance covered (approximately 75% increase in distance covered), whereas under the FRMS application the corresponding percentages are between approximately 6.3% and 25.8%. Accordingly, the improvement of additional time consumed for bypassing the hypothetical obstacle through the use of the web-tool is varying between 68.82% and 49.27% for the scenarios C and D, respectively.

As a result, using the FRMS not only helps the Forest Office cut back the costs of repairing the damages of the forest facilities like stuck drainage pipes, but can also take a major role in the information of the transports of all kinds through the forest roads.

Overall, from the previous analysis, results and examples, it is seen that using the proposed computer application results in considerable improvements in forest management parameters, such as distance covered and time consumed, enhancing thus the optimal utilization of any forest road network.

4. Conclusions

The main objective of the current study was the proposal and development of a decision making web-application that aims to assist in the management of forest road networks in a holistic way. The proposed application provides an easy to use and useful tool that combines geoprocessing and geospatial technologies for the efficient optimization of the management of a forest road network. With the spatial information provided, there is a more prudent picture of the state of the forest road network of each forest complex. In this way, practical and reliable solutions can be proposed and found, so that by imprinting them on three-dimensional ground models, they will help in making more reliable decisions.

Overall, the proposed forest road management web-based tool has been shown to give satisfactory results, by the optimization of both resources used and time consumed. Nevertheless, the adoption of this forest road network management model has been proven to be a useful decision making tool, although it needs further improvements. Finally, among the strengths of the proposed tool, one may prioritize the fact that the former is a light application, meaning that the end point user does not have to have a computer that cost much. It is costless since it is an open source application in all of the aspects of development and it can be modified to work with any open source type of database or program and finally it can be used as a PPGIS (Public Participation GIS) system to enrich the data gathering from other sources rather than only emergency calls. As regards potential weaknesses, these include the fact that certain aspects of the application are designed to be carried out manually instead of being fully automatic. In addition, no sensors or cameras are currently available for auto feedback.

However, these limitations are the subject of ongoing research towards the improvement of the current web application.

References

[1] Talebi, M., Majnounian, B., Abdi, E., and Tehrani, F. B. 2015. "Developing a GIS Database for Forest Road Management in Arasbaran Forest, Iran." *Forest Sci. Technol.* 11 (1): 27-35.

[2] Najafi, A., and Richards, E. W. 2013. "Designing a Forest Road Network Using Mixed Integer Programming." *Croatian Journal of Forest Engineering* 34 (1): 17-30.

[3] Abdi, E., Majnounian, B., Darvishsefat, A., Masha-yekhi, Z., and Sessions, J. 2009. "A GIS-MCE Based Model for Forest Road Planning." *J. Fo. Sci.* 55 (4): 171-6.

[4] Hayati, E., Majnounian, B., and Abdi, E. 2012. "Qualitative Evaluation and Optimization of Forest Road Network to Minimize Total Costs and Environmental Impacts." *iForest* 5: 121-5. Accessed June 05, 2012. http://www.sisef.it/iforest/contents/?id=ifor0610-009.

[5] Arnáez, J., Larrea, V., and Ortigosa, L. 2004. "Surface Runoff and Soil Erosion on Unpaved Forest Roads from Rainfall Simulation Tests in Northeaster Spain." *Catena* 57 (1): 1-14. doi:10.1016/j.catena. 2003.09.002.

[6] Correa, C. M. C., Roloff, G., and Silva, I. C. 2007. "Real and Estimative Erosion through RUSLE from Forest Roads in Two Relief Conditions and Four Soils Profile". *Sci. For.* 35 (76): 57-66.

[7] Colchero, F., Conde, D. A., Manterola, C., Chávez, C., Rivera, A., and Ceballos, G. 2011. "Jaguars on the Move: Modelling Movement to Mitigate Fragmentation from Road Expansion in the Mayan Forest." *Anim. Conserv.* 14 (2): 158-66. doi:10.1111/j.1469-1795.2010.00406.x.

[8] Ali, J., Benjaminsen, T. A., Hammad, A. A., and Dick, Ø. B. 2005. "The Road to Deforestation: An Assessment of Forest Loss and Its Causes in Basho Valley, Northern Pakistan." *Global Environ. Chang* 15 (4): 370-80.

[9] Demir, M. 2007. "Impacts, Management and Functional Planning Criterion of Forest Road Network System in Turkey." *Transp Res. Part A: Policy and Practice* 41: 56-68.

[10] Enache, A., Stampfer, K., Ciobanu, V., Brânzea, O., and Duţă, C. 2011. "Forest Road Network Planning with State of the Art Tools in a Private Forest District from Lower Austria." *Bull. Transilv. Univ. Brasov. Ser. III-Forestry. Wood Industry. Agricultural Food Engineering* 4 (53): 33-40.

[11] Hayati, E., Majnounian, B., Abdi, E., Sessions, J., and Makhdoum, M. 2013. "An Expert-based Approach to Forest Road Network Planning by Combining Delphi and Spatial Multi-criteria Evaluation." *Environ. Monit. Assess*. 185 (2): 1767-76.

[12] Parsakhoo, A., Lotfalian, M., and Hosseini, S. A. 2010. "Forest Roads Planning and Construction in Iranian Forestry." *J. Civ. Eng. Constr. Technol.* 1 (1): 14-8.

[13] Dragoi, M., Palaghianu, C., and Miron-Onciul, M. 2015. "Benefit, Cost and Risk Analysis on Extending the Forest Roads Network: A Case Study in Crasna Valley (Romania)." *Ann. for Res.* 58 (2): 333-45.

[14] Kantartzis, A. 2015. "Databases of Forest Road Construction in the Context of Forest Cadastral." Ph.D. Thesis. Democritus University of Thrace. (available at: https://www.didaktorika.gr/eadd/handle/10442/36578).

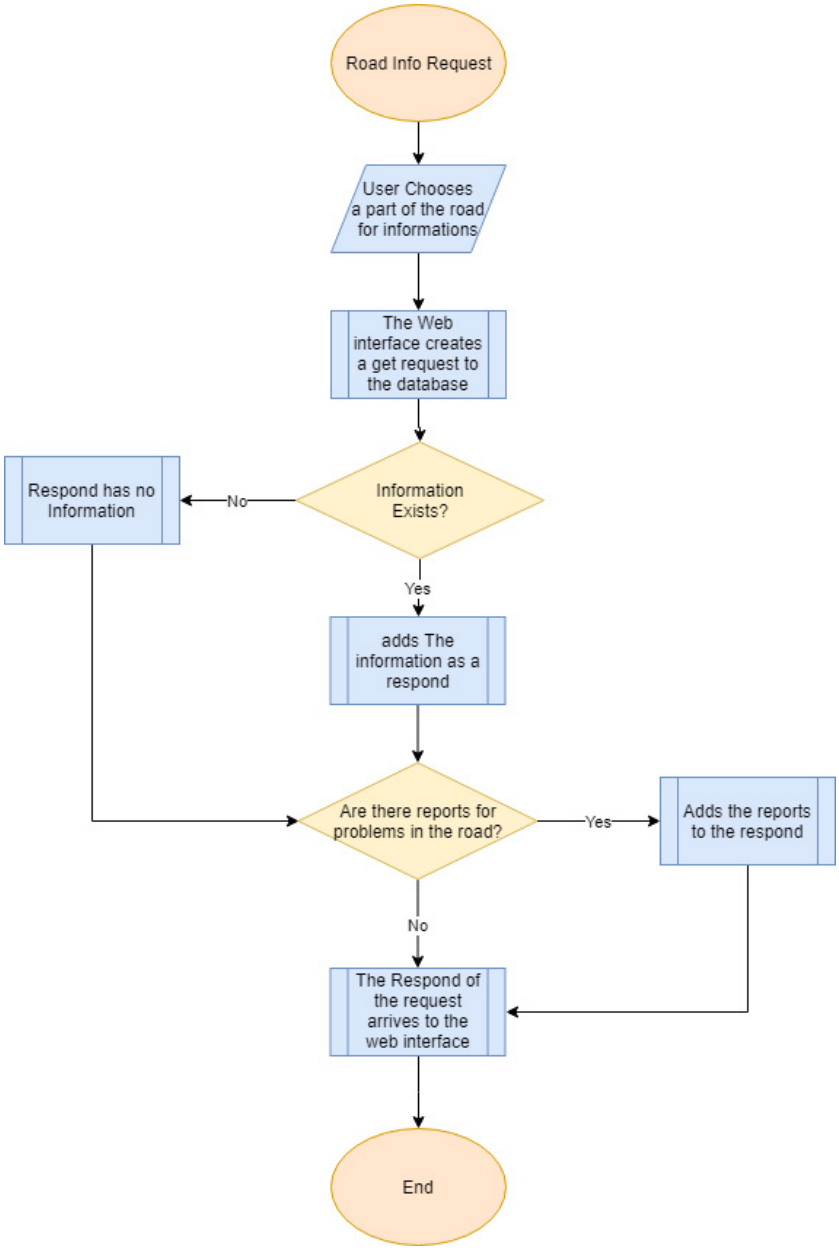
[15] Egan, A., Jenkins,A., and Rowe, J. 1996. "Forest Roads in West Virginia, USA: Identifying Issues and Challenges." *Forest Sci. Technol*. 7 (3): 33-40.

[16] Karlsson, J., Rönnqvist, M., and Frisk, M. 2006. "Road Opt: A Decision Support System for Road Upgrading in Forestry." *Scand. J. For Res*. 21 (1): 5-15.

[17] Gumus, S., Acar, H. H., and Toksoy, D. 2008. "Functional Forest Road Network Planning by Consideration of Environmental Impact Assessment for Wood Harvesting." *Environ. Monit. Assess.* 142: 109-16.

[18] Erler, J. 2000. "Forsttechnik: Verfahrensbewertung". Stuttgart: Eugen Ulmer GmbH & Co. (in German)

Appendix



Flowchart of the separate steps of FRMP application.

Journal of Environmental Science and Engineering A 7 (2018) 22-29
doi:10.17265/2162-5298/2018.01.003

Coastal Abrasion and Accretion Studies of West Sumatera Province in Period 2003-2016

Haryani[1], Agus Irianto[2] and Nurhasan Syah[3]

1. Faculty of Civil Engineering and Planning, Bung Hatta University, Padang City 25133, Indonesia

2. Faculty of Economi, State University of Padang, Padang City 25132, Indonesia

3. Faculty of Engineering, State University of Padang, Padang City 25132, Indonesia

Abstract: West Sumatera province has 19 cities and regencies where 6 of them often experience abrasion and accretion disaster, because it is a coastal area directly adjacent to the Indian Ocean. This study aims to examine the characteristics of abrasion and accretion disasters along the coast of West Sumatera Province from 2003 to 2016. By knowing the characteristics of abrasion and accretion from 2003 and 2016, it will be known which beaches are experiencing abrasion or accretion. This research is qualitative and quantitative descriptive research with GIS (Geographic Information System) analysis method to get characteristic of abrasion and accretion disaster in coastal area of West Sumatera. There has been a disaster of abrasion and accretion in 32 points spread across 6 districts and cities, namely West Pasaman District, Agam Regency, Padang Pariaman District, Pariaman City, Padang City and Padang Pariaman District, an abrasion disaster in the coastal area of West Sumatera Province of 732.69 Ha and 55.4 Ha of acres. This proves that the abrasion debacle causes the decrease of land in West Sumatera Province which is big enough that is average 56.3 Ha/year, while the addition of land is only 4.26 Ha/year. The farthest abrasion disasters are located in South Pesisir Regency, which is 45.70 m or 3.52 m/year on average. While the farthest accretion is in the South Pesisir Regency, and is as far as 36.91 m or an average of 2.84 m/year.

Key words: Abrasion, accretion, coastal, disaster, West Sumatera.

1. Introduction

According to the Law of the Republic of Indonesia Number 24 Year 2007, disaster is an event or series of events that threaten and disrupt the lives and livelihoods of people caused by both natural and/or non-natural factors and human factors resulting in the occurrence of human lives, environmental damage, property loss and psychological impact. Disasters occur because of threats, impacts and vulnerabilities [1]. Indonesia region is one of the countries with high potential to experience natural disasters such as tsunamis, volcanoes and landslides. The high potential of disaster, especially the tsunami and the eruption of Mount Merapi is due to the Indonesian territory consists of the order and geological process located on three plates of the earth that is Indo-Australia, Eurasia and Pacific. According to BNPB (Badan Nasional Penanggulangan Bencana) 2016 data [2, 3], 80% of Indonesia is at risk of hydrometeorological disaster. There are 10 types of disasters that are at risk in Indonesia, such as floods, flash floods, extreme weather, abrasion and extreme waves, earthquakes, forest and land fires, drought, eruption of Mount Merapi, landslides and tsunamis. Compared to the number of disasters by 2015, the incidence of disasters in 2016 increased by 35%. Of these, 92% of the disaster this year is a hydrometeorological disaster that is dominated by floods, landslides and tornadoes.

During 2016, there were 766 floods, 612 landslides, 669 tornadoes, 74 floods and landslide combinations, 178 forest and land fires, 13 earthquakes, 7 volcanoes and 23 tidal waves and abrasion.

In Indonesia, the risk of abrasion and extreme wave disasters occur in an area of 1,888,085 Ha, with the

Corresponding author: Haryani, MT, Dr, main research fields: coastal spatial planning, disaster mitigation and tourism.

number of people exposed to 4,917,327 and can cause physical losses of Rp. 22,042,350 M, economic loss Rp. 1,290,842 M and environmental damage 460,252 Ha [2].

On the island of Sumatera, there are 21 cities/districts are at high risk of disaster. The dominant disaster risks are floods, earthquakes, forest and land fires, landslides, tsunamis, volcanic eruptions and flash floods. The target of declining disaster risk index in Indonesia is 30% up to the year 2019 with the strategy of increasing the capacity index in the Regency/City. Increased capacity index among others is the readiness of institutional components, early warning, education, mitigation and preparedness. In line with the RPJMN (Rencana Pembangunan Jangka Menengah Nasional) policy and strategy direction [4], the reduction of vulnerability to disaster is one of building and growing local wisdom in development and disaster [5-7].

Historically, West Sumatera is an area that has experienced many disasters. The previous disasters in West Sumatera were ranked by the highest percentage 43% of floods, 18% of landslides, 7% of fire, floods and landslides, 6% of earthquake, 3% of tide/ abrasion, and 7% of other disasters [3]. These disasters have caused a lot of casualties, damages, and losses that are not small either from the community or the government of Indonesia.

Although the tidal wave disaster only happened as much as 3%, according to research Bambang Istijono [8], from 1918 has happened erosion of beach Padang average 2.20 m/year. The coastline of Padang is relatively straight, most of the beach is composed of sand, behind the coast of a vast alluvial plain. The basic concept of Padang beach abrasion is to reduce the influence of sea wave energy with the installation of 0.50-1.50 m diameter stone and coastal sand threatened its stability. Groin with stone material that fitted into the sea 15-25 m with 50 m intervals and coastal dikes is a form of coastal protection, and is quite successful in the city of Padang, which began built in 1974 until now.

The result of Haryani, H.'s research [9], the level of disaster vulnerability that threatens Padang Beach (case study of Pasie Nan Tigo Sub-district Koto Tangah Sub-district) consists of main disaster and catastrophic disaster. Major disasters included, storms and tsunami threats are key vulnerabilities, coastal abrasion and second tidal wave vulnerability, sea water intrusion and third susceptibility sedimentation and low vulnerability are floods. As for catastrophic disasters that occupy major vulnerabilities are the economic vulnerability, the two physical vulnerabilities, the vulnerability of the three environments and the vulnerability of all four social vulnerabilities.

Meanwhile, from 19 cities and regencies in West Sumatera Province, 6 of them are coastal cities/regencies bordering the Indian Ocean. Cities and coastal districts are West Pasaman District, Agam District, Padang Pariaman District, Pariaman City, Padang City and South Coast District. City and coastal districts are generally a densely populated area of Padang City which is the capital of the Province. The geographical condition of West Sumatera Province bordering the Indian Ocean, has the potential for abrasion and accretion. Therefore, the problem in this research is how the characteristics of coastal abrasion and accretion disaster from 2003 and 2016 in coastal region of West Sumatera Province.

The purpose of this study is to examine the characteristics of abrasion and accretion disasters from 2003 and 2016 in the coastal areas of West Sumatera Province and any coast that experienced abrasion or accretion.

2. Materials And Methods

2.1 Research Approach

The study approach method used is descriptive quantitative. Quantitative descriptive approach, ie data and information obtained, processed and presented

using the forms of frequency tables and percentages. The coastline map of 2003 with 2016 shoreline map overlap (overlay). The results obtained are any beach that has abrasion and or accretion.

2.2 Method of Collecting Data

Data collection method used is by secondary survey method. Secondary survey is a method by collecting data from various agencies and literature studies related to the substance of the object of study in the form of thematic maps of books and articles in the relevant scientific journals that are processed into one data and information. Detailed maps (secondary data) and sources can be seen in Table 1.

2.3 Analysis Method

The method of analysis used is the coastline comparison method of 2003 with the coastline of 2016. The method of analysis can be seen in Table 2.

3. Results and Discussion

3.1 The Development of Abrasion and Accretion in 2003 and 2016

The results of coastal abrasion and accretion analyzes by overlapping the 2003 map with 2016 map of the coastline of Western Sumatera are obtained coastline that has abrasion (coastline retreat) or accretion (coastal addition). Map analysis is done by delineation of land and water boundaries to obtain coastline covered by vegetation. Non-vegetated terrestrial terrain is further explained into water pixels (sea). In contrast to the SWIR-1 band ratio with the Green band (b5/b2 at Landsat-7; b6/b3 at Landsat-8), the coastline of the area covered by sand and soil is obtained.

The aeriality and accumulation of the West Sumatera coastline from 2003 to 2016 can be seen in Table 3.

Table 1 Types of data and source.

Data	Data type	Analysis method	Data source
Landsat ETM image data of 2003, Landsat OLI image data of 2016.	Secondary data: satellite imagery from landsat obtained from USGS (U.S. Geological Survey).	Using Band-Ratio and Single Band Methods to obtain delineation of terrestrial and water boundaries (pixel value limits) for the purpose of obtaining shorelines in each image of both ETM landscapes in 2003 and OLI landscapes 2016.	USGS U.S. Department of the Interior USGS or the Department of Home Affairs of the USGS.

Table 2 Analysis method.

The first stage	Phase two	Phase third	Phase four
Landsat ETM image data of 2003 and Landsat OLI in 2016 or acquisitions that year adjacent to the main criteria of each selected dataset is cloud-free, Landsat dataset requirements used for analysis and download are cloud content data ≤ 10% and not yet defect on SLC (Scan Line Corrector).	For ease of analysis, the multi-spectral band types of the two datasets (Landsat-7 ETM and Landsat-8 OLI) are made in the form of band layer stacking (combined) in each dataset. Because the scope of research area (Coastal of West Sumatera) need 3 scene (path/row), then with step like this, resulted 6 pieces file stacking for requirement of coastline analysis.	Delineation of land and water boundaries to obtain coastline using Band-Ratio method to obtain more informative pixel value limits. In the Band-Ratio method, the ratio of NIR bands with Green bands (b4/b2 at Landsat-7; b5/b3 at Landsat-8) would result in a land-water boundary in coastal areas covered by vegetation. Non-vegetated terrestrial terrain is further explained into water pixels (sea). In contrast to the SWIR-1 band ratio with the Green band (b5/b2 at Landsat-7; b6/b3 at Landsat-8), the coastline of the area covered by sand and soil is obtained.	To facilitate the extraction of sea-border information which will be a coastline feature, a composite band or false color combination is used to display the limit of each observed object. The result of converting raster to vector. This polyline vector file is the same vertex size as the spatial resolution of the original dataset (Landsat ETM and Landsat OLI) of 30 meters. So to refine and edit it done repairs. Improvements are made using the line smooth tools in ArcGIS.

Table 3 Disaster abrasion disasters and accretion West Sumatera Province 2003-2016.

No	Cordiant		Long (m)	Change	Location
	X	Y			
1	623020	9934204	21.30	Accretion	Pariaman
2	618248	9941318	26.63	Accretion	Padang Pariaman
3	594519	9964605	27.22	Accretion	Agam
4	706582	9766915	16.72	Accretion	Pessel
5	696741	9801707	27.61	Accretion	Pessel
6	682308	9822788	28.96	Accretion	Pessel
7	676526	9846948	12.93	Accretion	Pessel
8	674485	9850775	36.91	Accretion	Pessel
9	638703	9916028	23.73	Abrasion	Padang Pariaman
10	637659	9916994	24.26	Abrasion	Padang Pariaman
11	635030	9919600	14.80	Abrasion	Padang Pariaman
12	623781	9932734	18.77	Abrasion	Pariaman
13	616836	9943023	7.66	Abrasion	Padang Pariaman
14	595941	9963671	21.42	Abrasion	Agam
15	597213	9962799	17.65	Abrasion	Agam
16	591843	9966170	17.40	Abrasion	Agam
17	589217	9972094	23.40	Abrasion	Agam
18	585107	9981676	28.98	Abrasion	Pasaman Barat
19	584171	9989685	24.72	Abrasion	Pasaman Barat
20	546839	10016208	22.69	Abrasion	Pasaman Barat
21	720378	9732211	16.57	Abrasion	Pesisir Selatan
22	712287	9740537	38.12	Abrasion	Pesisir Selatan
23	690377	9811442	26.18	Abrasion	Pesisir Selatan
24	689557	9812399	24.74	Abrasion	Pesisir Selatan
25	682175	9824383	16.35	Abrasion	Pesisir Selatan
26	682077	9825964	35.14	Abrasion	Pesisir Selatan
27	680472	9830554	18.70	Abrasion	Pesisir Selatan
28	677849	9835173	45.70	Abrasion	Pesisir Selatan
29	674753	9843750	31.37	Abrasion	Pesisir Selatan
30	651126	9890829	10.54	Abrasion	Padang
31	650338	9892911	13.55	Accretion	Padang
32	647709	9905662	15.68	Abrasion	Padang

Table 4 Abrasion beach at District of Pasaman Barat 2003-2016.

No.	Long (m)	Abrasion/Accretion
1	28.98	Abrasion
2	24.72	Abrasion
3	22.69	Abrasion

There are 32 observed points of abrasion and accretion along the coast of West Sumatera period 2003 to 2016. Here are the results of the analysis of abrasion and accretion disasters that occurred in each region in the City/District period of 2003 until 2016. In Pasaman Barat District during the period 2003-2016 observed a third (3) point abrasion occurred. The abrasion occurred on average as far as 25.46 m, the abrasion eroded the furthest coast 28.98 m and the closest 22.69 m, while the accretion is not available in Pasaman Barat Kabuapten. More can be seen in Table 4.

In Kabupaten Agam, there are 5 locations observed abrasion or accretion where 4 locations occur abrasion and 1 location of accretion. Abrasion occurs as far as 23.40 m while accretion occurs as far as 27.22 m. In contrast to West Pasaman District which only happened abrasion, in Agam Regency happened abrasion, average as far as 19.97 m at the same time happened accretion. The completeness of the abrasion point and the magnitude of each accretion and accretion can be seen in Table 5.

Accretion and abrasion occur also in Padang Pariaman District. Average abrasion occurred as far as 17.61 m, where abrasion happened at 5 point, while accretion happened at 1 point as far as 26.63 m in Table 6. Almost the same as Pariaman City happened

Table 5 Abrasion of beach and accretion in District of Agam 2003-2016.

No.	Long (m)	Abrasion/Accretion
1	27.22	Abrasion
2	21.42	Abrasion
3	17.65	Abrasion
4	17.40	Abrasion
5	23.40	Abrasion

Table 6 Abrasion of beach and accretion in District of Padang Pariaman 2003-2016.

No.	Long (m)	Abrasion/Accretion
1	26.63	Accretion
2	23.73	Abrasion
3	24.26	Abrasion
4	14.80	Abrasion
5	7.66	Abrasion

Table 7 Abrasion of beach and accretion in Pariaman City 2003-2016.

No.	Long (m)	Abrasion/Accretion
1	21.30	Accretion
2	18.77	Abrasion

1 point accretion as far as 21.30 m and 1 point abrasion as far as 18.77 m. More abrasion and accretion that happened in District of Padang Pariaman and Pariaman City can be seen in Table 7.

In the city of Padang, abrasion occurs at 2 points i.e. as far as 10.5 m and 15.68 m while accretion is at 1 point as far as 13.55 m in Table 8.

Compared with the City/District in West Sumatera, the largest distribution of abrasion and accretion is in District of Pesisir Selatan. There are 14 abrasion and accretion sites with 5 accretion points and 9 coastal abrasion points. Furthest acceleration of 36.91 m stretch of farthest abrasion 45.7 m and nearest 16.35 m. More abrasion and accretion that happened in Padang City and Pesisir Selatan Regency period 2003 to 2016 can be seen in Table 9.

3.2 Wide Area of Abrasion and Sumatera Coastal Accretion Analysis 2003-2016

With the same method, the results of the analysis of the area of abrasion and accretion that occurred coastal of West Sumatera Province by overlapping map of year 2003 with map of year 2016 obtained coastline which have abrasion (coastline retreat) or accretion (addition of beach) and length of area experiencing changes. By knowing the length and the changes that occur to the coastline, the coastal/coastal area that is abrasion or coastal accretion is obtained.

The results of the analysis of the area of abrasion and coastal accretion of West Sumatera for the period

Table 8 Abrasion of beach and accretion in Padang City 2003-2016.

No.	Long (m)	Abrasion/Accretion
1	10.54	Abrasion
2	13.55	Accretion
3	15.68	Abrasion

Table 9 Abrasion of beach and accretion in District of Pesisir Selatan 2003-2016.

No.	Long (m)	Abrasion/Accretion
1	16.72	Accretion
2	27.61	Accretion
3	28.96	Accretion
4	12.93	Accretion
5	36.91	Accretion
6	16.57	Abrasion
7	38.12	Abrasion
8	26.18	Abrasion
9	24.74	Abrasion
10	16.35	Abrasion
11	35.14	Abrasion
12	18.70	Abrasion
13	45.70	Abrasion
14	31.37	Abrasion

of 2003-2016 can be seen in Table 10. There are 32 points that undergo changes in both abrasion and accretion during this period that are spread along the coast of West Sumatera Province. Distribution of abrasion and accretion that mostly occurred in the South Coast is 14 locations, which consists of 9 points abrasion and 5 beach accretion points. While the distribution of smallest abrasion and accretion location in Pariaman City is 2 points (abrasion and accretion).

In District of Pasaman Barat, there are only 3 coastal abrasion points without any accretion, but the abrasion area in Kabuapten is the second largest after abrasion and coastal accretion in District of South Coastal is 425.11 Ha. More can be seen in Table 11. Significant loss of land in District of West Pasaman due to coastal abrasion, it is feared that the day is getting bigger because it is not accompanied by accretion (addition of land).

In Kabupaten Agam, there are 5 locations of abrasion and accretion, consisting of abrasion at 4 points and

Table 10 Space abrasion beach and accretion in West Sumatera Province 2003-2016.

No.	Kordinat		Perubahan	Lokasi	Luas (Ha)
	X	Y			
1	638703	9916028	Abrasion	Pariaman	18.66
2	637659	9916994	Abrasion	Padang Pariaman	3.32
3	635030	9919600	Abrasion	Agam	8.30
4	623781	9932734	Abrasion	Pessel	2.03
5	623020	9934204	Accretion	Pessel	4.84
6	618248	9941318	Accretion	Pessel	3.42
7	616836	9943023	Abrasion	Pessel	3.68
8	595941	9963671	Abrasion	Pessel	6.59
9	597213	9962799	Abrasion	Padang Pariaman	2.25
10	594519	9964605	Accretion	Padang Pariaman	9.86
11	591843	9966170	Abrasion	Padang Pariaman	21.78
12	589217	9972094	Abrasion	Pariaman	8.70
13	585107	9981676	Abrasion	Padang Pariaman	133.42
14	584171	9989685	Abrasion	Agam	265.90
15	546839	10016208	Abrasion	Agam	25.79
16	720378	9732211	Abrasion	Agam	16.89
17	712287	9740537	Abrasion	Agam	108.97
18	706582	9766915	Accretion	Pasaman Barat	13.58
19	696741	9801707	Accretion	Pasaman Barat	4.09
20	690377	9811442	Abrasion	Pasaman Barat	7.77
21	689557	9812399	Abrasion	Pesisir Selatan	7.79
22	682308	9822788	Accretion	Pesisir Selatan	2.74
23	682175	9824383	Abrasion	Pesisir Selatan	1.57
24	682077	9825964	Abrasion	Pesisir Selatan	27.06
25	680472	9830554	Abrasion	Pesisir Selatan	9.47
26	677849	9835173	Abrasion	Pesisir Selatan	21.62
27	674753	9843750	Abrasion	Pesisir Selatan	25.39
28	676526	9846948	Accretion	Pesisir Selatan	10.28
29	674485	9850775	Accretion	Pesisir Selatan	6.26
30	650338	9892911	Accretion	Padang	0.33
31	651126	9890829	Abrasion	Padang	1.94
32	647709	9905662	Abrasion	Padang	3.80

Table 11 Space abrasion beach and accession in District of West Pasaman 2003-2016.

No.	Long (m)	Large (ha)	Abrasion/Accretion
1	28.98	133.42	Abrasion
2	24.72	265.90	Abrasion
3	22.69	25.79	Abrasion
	Total	425.11	Abrasion

Table 12 Space abrasion beach and accretion in District of Agam 2003-2016.

No.	Long (m)	Large (ha)	Abrasion/Accretion
1	27.22	9.86	Accretion
2	21.42	6.59	Abrasion
3	17.65	2.25	Abrasion
4	17.40	21.78	Abrasion
5	23.40	8.70	Abrasion
	Total	9.86	Accretion
		39.32	Abrasion

only 1 point of accretion. The area of abrasion that occurs is 39.32 Ha and accretion area of 9.86. This means that the reduced land area due to abrasion is not proportional to the extent of coastal accretion that occurs. More can be seen in Table 12.

Likewise in Padang Pariaman there are 5 locations consisting of abrasion at 4 points and accretion at 1 point. The area of abrasion disaster in Padang Pariaman beach is 33.96 Ha, while accretion is only 3.42 Ha in Table 13. This also shows no equivalent land area lost with the addition of land in District of Padang Pariaman.

In Pariaman City, there is only 1 point of abrasion location and 1 coastal accretion point with maaing of 2.03 Ha abrasion area and 4.84 Ha accretion area. This is different from other areas where the area of abrasion is smaller (2.03 Ha) than the accretion area greater than twice the abrasion of 4.84 Ha. More can be seen in Table 14.

As the capital of West Sumatera Province, Padang City did not escape the disaster of abrasion and coastal accretion. There has been a reduction of land area due to coastal abrasion of 5.74 Ha while land addition is only 0.33 Ha. This condition is very prudent considering that as the capital of the Province, Padang

Table 13 Space abrasion beach and accretion in District of Padang Pariaman 2003-2016.

No.	Long (m)	Large (ha)	Abrasion/Accretion
1	26.63	3.42	Accretion
2	23.73	18.66	Abrasion
3	24.26	3.32	Abrasion
4	14.80	8.30	Abrasion
5	7.66	3.68	Abrasion
	Total	3.42	Accretion
		33.96	Abrasion

Table 14 Space abrasion beach and accretion in the Pariaman City 2003-2016.

No.	Long (m)	Large (ha)	Abrasion/Accretion
1	21.30	4.84	Accretion
2	18.77	2.03	Abrasion

City requires a fairly high land for development. From the analysis, it can be concluded that on average, there is a reduction of 0.44 Ha/year. This figure is quite high considering the city of Padang is a coastal town that is quite dense population and area terbangunnya.

More coastal abrasion and accretion data that happened last 13 year in Padang City can be seen in Table 15.

Most abrasion and accretion disasters are found in District of Pesisir Selatan which is spread over 14 points. The abrasion disaster for the last 13 years is 226.53 Ha and 36.95 Ha accretion in Table 16. On average, there has been a reduction of land area of 17.4 Ha and this is a big enough figure to be concerned by the Pesisir Selatan District Government.

The largest coastal eruption occurring on the coast of West Sumatera in the last 13 years is District of West Pasaman which is 265.90 Ha and in District of Pesisir Selatan of 108.97 Ha. This is very worrying if the continent of the mainland will be reduced especially in coastal areas. The increasingly diminishing land area will trigger land use problems and land tenure status.

While the accretion is the largest addition of land that is found in District of Pesisir Selatan of 10.28 Ha and District of Agam covering 9.86 Ha. Extensive accretion is the addition of coastal land area in West

Table 15 Space abrasion beach and accretion in Padang City 2003-2016.

No.	Long (m)	Large (ha)	Abrasion/Accretion
1	10.54	1.94	Abrasion
2	13.55	0.33	Accretion
3	15.68	3.80	Abrasion
	Total	0.33	Accretion
		5.74	Abrasion

Table 16 Space abrasive beach and accession in District of Pesisir South 2003-2016.

No.	Long (m)	Large (ha)	Abrasion/Accretion
1	16.72	13.58	Accretion
2	27.61	4.09	Accretion
3	28.96	2.74	Accretion
4	12.93	10.28	Accretion
5	36.91	6.26	Accretion
6	16.57	16.89	Abrasion
7	38.12	108.97	Abrasion
8	26.18	7.77	Abrasion
9	24.74	7.79	Abrasion
10	16.35	1.57	Abrasion
11	35.14	27.06	Abrasion
12	18.70	9.47	Abrasion
13	45.70	21.62	Abrasion
14	31.37	25.39	Abrasion
	Total	36.95	Accretion
		226.53	Abrasion

Table 17 Space abrasion beach and accretion in West Sumatera Province 2003-2016.

No.	County/town	Abrasion (Ha)	Accretion (Ha)
1	Pasaman Barat	425.11	-
2	Agam	39.32	9.86
3	Padang Pariaman	33.96	3.42
4	Pariaman	2.03	4.84
5	Padang	5.74	0.33
6	Pesisir Selatan	226.53	36.95
	Amount	732.69	55.4

Sumatera region only 55.4 ha, and much smaller land loss due to coast abrasion that is equal to 732.69 Ha in Table 17.

4. Conclusion

From 2003 to 2016 (13 years of observation), on the coast of West Sumatera Province there has been abrasion and accretion disaster in 32 points spread

across 6 districts and cities, namely Pasaman Barat District, Agam District, Padang Pariaman District, Pariaman City, Padang City and Pesisir Selatan District. The highest number of points of abrasion and accretion is found in Pesisir Selatan District and only 2 points of abrasion and accretion are in Pariaman City.

Congratulations 13 years of observation, abrasion disaster in the coastal area of West Sumatera Province of 732.69 Ha and 55.4 Ha of acres. This proves that the abrasion debacle causes the decrease of land in West Sumatera Province which is big enough that is average 56.3 Ha/year, while the addition of land is only 4.26 Ha/year. This figure proves insignificant between the extent of coastal abrasion and coastal accretion in West Sumatera.

The farthest abrasion disasters are located in South Coast Regency as far as 45.70 m or 3.52 m/year average. While the farthest accretion is in the South Coast Regency is as far as 36.91 or an average of 2.84 m/year. From the rate of coastline retreat and the advance of coastline in Pesisir Selatan, the addition of land (accretion) can be as far as 2.84 m/year.

References

[1] Law of the Republic of Indonesia Number 24. 2007. *Regarding Disaster Management*. Jakarta: Department of Home Affairs.

[2] BNPB (Badan Nasional Penanggulangan Bencana). 2016. *Decrease of Disaster Risk Index in Indonesia*. Disaster Eradication National Agency.

[3] BPNB. 2007. "Guidance on the Characteristics of Disaster and Mitigation Measures in Indonesia." In *Decrease of Disaster Risk Index in Indonesia,* edited by Triutomo, Sugeng, Widjaja, Wisnu, B., Amri, and Robi, M. Jakarta: Disaster Eradication National Agency.

[4] RPJMN (Rencana Pembangunan Jangka Menengah Nasional). 2015. *Indonesia National Medium-Scale Development Plan 2015-2019.* Disaster Division.

[5] Bengen, G. D. 2002. *Coastal and Marine Ecosystems and Natural Resources and Principles of Management.* Bogor: IPB.

[6] Dahuri, R. 2001. *Integrated Coastal and Marine Resource Management.* Jakarta: PT Pradnya Paramita.

[7] Diposaptono, S., Budiman, and Agung, F. 2009. *Dealing with Climate Change in Coastal Areas and Isles.* Bogor: Buku Ilmiah Populer.

[8] Istijono, B. 2013. "Environmental Review and Countermeasures of Coastal Abrasion in Padang, West Sumatera." *Jurnal Rekayasa Sipil.* 9: 2.

[9] Haryani, H. 2012. "Disaster Mitigation Model in Coastal Area with Community Empowerment." *Tataloka National Journal* 14: 3.

Journal of Environmental Science and Engineering A 7 (2018) 30-33
doi:10.17265/2162-5298/2018.01.004

Economic Analysis of the Utilization of Disused Biomass from the Agricultural Activity in the Region of Thessaloniki

Odysseas Kopsidas[1], Andreas Hadjixenophontos[1] and Athanasios Anastasiou[2]

1. School of Economics & Business, Pafos 8042, Cyprus

2. Department of Economics, University of Peloponnese, Tripolis 22100, Greece

Abstract: This paper aims to describe an environmental problem, the accumulation of waste biomass, which is a parameter of property devaluation and a reduction in the living standards of the inhabitants of the wider area of Thessaloniki. In this study, the respondents are 250 interviewees who answered the questions in the questionnaire. In the present study, the dependent WTA (Willingness to Accept) variable is determined in classes and is measured in an amount (currency units). After determining the minimum amount available to farmers (WTA) to participate in the collection and recovery of discarded biomass, averaged at € 28.3. The economic analysis of the utilization of discharged biomass involves matching the environmental to the socio-economic benefit. A solution is proposed for the optimum disposal site of the discharged biomass by multicriteria selection including alternative options to address endogenous difficulties or external factors that necessitate a change in the first optimal solution.

Key words: Biomass, WTA (Willingness to Accept), multicriteria analysis, land value, environmental cost.

1. Introduction

The decision to adopt a strategy to solve the problem of the collection and utilization of waste biomass that is a residual of agricultural activity in the wider area of Thessaloniki is a parameter for determining the value of real estate plots in the area [1]. The identification of the research objective is the economic analysis of the activity of collecting and exploiting farm residues, assessing the compensation available to farmers to participate in the activity [2]. The objective is also to minimize the environmental burden, which ecologically damages the area, decreases the incomes of residents and reduces the value of real estate [3].

The economic analysis of the utilization of discharged biomass involves matching the environmental to the socio-economic benefit [4]. By analogy, economic analysis of the principle "thinks locally, act globally" and "think globally, act locally" (now known on a theoretical and practical basis). Although these principles usually have atmospheric pollution, they can be used in solid waste [5].

2. Methodology

The analysis of the subject may include qualitative and quantitative characteristics. This is preceded by a qualitative analysis, which indicates one or more directions quantified later. The quantitative analysis follows in order to determine the WTA (Willingness to Accept) variable as well as to find the optimal site selection for depositing the discharged biomass after the rating of the specialists in a multi-criteria panel.

Considering that: (a) energy costs are critical to the cost of transporting an extremely cheap product or waste, even if it acquires (due to treatment) a relatively higher added value; and (b) the collection network/transport/transshipment plan is planned to operate over a time horizon exceeding the depreciation time of biomass treatment plants, it is

Corresponding author: Odysseas Kopsidas, Ph.D., research fields: public economics and environmental economics.

necessary to forecast the long-term and long-term fuel prices, in particular petroleum products, natural gas and biofuels [6].

The alternative quantitative models used and their scenarios, in the form of different parameter values and associated conditions, should be studied by emphasizing the analysis of failed predictions and the investigation of the causes of this failure and the collection assumptions so that they can be reused in similar cases under a CBR (Case Based Reasoning) process [7]. These alternatives are presented hierarchically in the multicriteria Table 1.

The estimation of the compensation that farmers are willing to receive in order to participate in the activity of collecting and utilizing the disposed biomass is realized by in situ questioning and the synthesis of the alternatives of the problem is done by multi-criteria analysis. The criteria for choosing the best solution are: capital/fixed and operating/variable costs, environmental burden, residents' response, expansion barriers and hazards. The combination of these criteria in conjunction with the scoring of each alternative dumping site of the discharged biomass will result in an optimal solution [8, 9].

3. Results

In this study, the respondents are 250 interviewees who answered the questions in the questionnaire. The choice of the statistical methodology for the analysis of the data is a function of two factors: first of the question, and second, of the nature of the measurements that preceded it. Statistical data analysis methods used to investigate the relationships between dependent and independent variables and the type of the variable, i.e. whether it is a categorical, ordered, interval variable, etc. [10, 11].

This study investigates and explores the relationship between the WTA that farmers receive from the wider region of Thessaloniki in order to allow one to collect the remains of their farm and the factors that affect them this financial compensation. In particular, the dependent variable is the desire to compensate (yes/no), while independent variables are the following: the number of hectares in relation to the average, the nominal management, the participation in the process and the age. The average price of compensation to be paid by farmers in the wider region of Thessaloniki to participate in the collection and utilization of disposed biomass is EUR 28.3 ($WTA_{average}$ = 28.3 euros).

Based on statistical theory, the recommended techniques are: crosstabs, logarithmic linear models, decision trees and monotonic regression. However, in statistical analysis literature, in data analysis guides with SPSS (Statistical Package for the Social Sciences) Statistics and in cases where the dependent variable is presented as a binary, the technique proposed is the logarithmic regression ignoring the nature of the dependent variables. In the present study, the dependent WTA variable is determined in classes and is measured in an amount (currency units). The probability of financial compensation of a farmer in the wider region of Thessaloniki to collect the remains of his farm is examined with the aid of the logarithmic regression model. Table 2 shows the coefficients of the final model along with their respective induction checks and confidence intervals.

The model therefore estimated by the sample data for the willingness or non-compensation of the farmer has the form: Ln·p/1-p = -3.195 + 0.427 (stremmas

Table 1 Results of the Logistic Regression process in terms of interaction in the model equation.

Variables	B	S.E.	Wald	df	Sig.	Exp (B)	Lower	Upper
Stremmas	0.427	0.433	0.972	1	0.324	1.532	0.656	3.580
Volunteer	0.518	0.653	0.630	1	0.427	1.679	0.467	6.032
Age	0.407	0.499	0.666	1	0.415	1.502	0.565	3.994
Management	0.468	0.272	2.951	1	0.086	1.597	0.936	2.724
Constant	-3.195	1.238	6.667	1	0.010	0.041		

Table 2 Assessment of the adaptation of the model to the sample data.

Step	-2Log likelihood	Cox & Snell R square	Nagelkerke R square
1	63.449	0.081	0.116

average) + 0.518 (volunteer) + 0.407 (age) + 0.468 (management).

Where p is the estimated probability of the farmer's pecuniary allowance in order to allow one to pick up and transport his farm waste. On the basis of the Wald criterion, a significant effect of the variable is interpreted by the four independent variables of the model in the configuration of the dependent variable values, it has no variable since Sig > 0.05 and thus the null assumption is accepted, i.e. $H_0 : b_i = 0$.

For the assessment of the model's adaptation to the sample data, it is done with the ratio of the maximum values of the likelihood ratio statistics for the complete model (L_0) and the model containing only the fixed term (L_0). The price of speech is as follows: $-2\ln (L_0/L_F) = 4.875$ (Model Chi – square), while the probability of a value so large for the X^2 distribution with four degrees of freedom is Sig. > 0.05. So the zero hypothesis H_0: $\beta_1 = \beta_2 = \beta_4 = 0$ is not rejected. Therefore, the four variables combined in the form of the logarithmic model do not contribute significantly to predicting the values of the dependent variable (Table 3).

In addition, Table 2 gives the value of the log-likelihood function (-2Log likelihood = 63.449) for the final model as well as the Cox & Snell determination coefficient (0.801) along with the Nagelkerke determination coefficient (0.116).

4. Roustness Analysis

The analysis of the robustness of the proposed solution for the collection of disposed biomass in the wider area of Thessaloniki leads the Local Authorities (Central Macedonia Region) to explore four sites U_1, U_2, U_3 and U_4, in order to select the most suitable storage area for the disposed biomass. The criteria taken into account are: operating or variable costs, fixed costs, environmental burden, residents' response, possible barriers to the expansion of the waste biomass collection area and risk. The weights w_i (i = 1, 2, …, 6) and the grades α_{ij} (j = 1,…,4) are given in Table 4, where the solution is also shown $U_4 > U_3 > U_2 > U_1$, where the symbol '>' means 'better than', because $S_4 < S_3 < S_2 < S_1$, where the smaller symbol has the usual algebraic meaning.

The technical characteristics of the Thessaloniki area include the average flow velocity of the torrents of the area, u = 36 m/h, the average flow of rivers Q = 1,000 m^3/h, the average irrigation supply is Q = 936 m^3.

Table 3 Assessment of the model's adaptation to the sample data.

Chi-square	df	Sig.
4.875	4	0.300

Table 4 Multi-criteria analysis to determine the optimal position.

F_i	Criteria	w_i	U_1 a_{i1}	U_2 a_{i2}	U_3 a_{i3}	U_4 a_{i4}	U_1 $w_i \cdot a_{i1}$	U_2 $w_i \cdot a_{i2}$	U_3 $w_i \cdot a_{i3}$	U_4 $w_i \cdot a_{i4}$
F_1	Operating cost	0.21	1.5	2.2	2.8	3.6	0.315	0.462	0.588	0.756
F_2	Fixed cost	0.27	2.5	3.2	2.9	2.1	0.675	0.864	0.783	0.567
F_3	Environmental burden	0.20	3.8	2.9	2.6	2.2	0.76	0.58	0.52	0.44
F_4	Opinion of residents	0.22	3.9	2.7	2.4	2.3	0.858	0.594	0.528	0.506
F_5	Reaction of residents	0.06	4.3	3.4	3	3.3	0.258	0.204	0.18	0.198
F_6	Danger	0.04	3.7	3	2.7	3.8	0.148	0.12	0.108	0.152
		1.00		sum S_j	3.014		2.824	2.707		2.619

5. Conclusion

The multicriteria option of the optimal alternative is a methodological tool for the gradual implementation of the proposed solution, which can be achieved by the sequential exploitation of the disposed biomass in the four alternative sites. This study can lead to the evaluation of the results for the first years of implementation and feedback of the subsystem for the maintenance decision making for the management of that biomass. Finally, the present study achieves the determination/implementing corrective actions and completing or revising planning for the coming years with regard to the collection and recovery of waste biomass.

References

[1] Ajzen, I., Brown, T. C., and Rosenthal, L. H. 1996. "Information Bias in Contingent Valuation: Effects of Personal Relevance, Quality of Information and Motivational Orientation." *Journal of Environmental Economics and Management* 30 (1): 43-57.

[2] Bedate, A., Herrero, L. C., and Sanz, J. A. 2004. "Economic Valuation of the Cultural Heritage: Application to Four Case Studies in Spain." *Journal of Cultural Heritage* 5 (1): 101-11.

[3] Kahneman, D., and Knetsch, L. J. 1992. "Valuing Public Goods: The Purchase of Moral Satisfaction." *Journal of Environmental Economics and Management* 22 (1): 57-70.

[4] Bateman, I., Munro, A., Rhodes, B., Starmer, C., and Sugden, R. 1997. "A Test of the Theory of Reference-Dependent Preferences." *The Quarterly Journal of Economics* 112 (2): 479-505.

[5] Brown, T. C. 2005. "Loss Aversion without the Endowment Effect, and Other Explanations for the WTA-WTP Disparity." *Journal of Economic Behavior and Organization* 57 (3): 367-79.

[6] Hanemann, W. M. 1991. "Willingness to Pay and Willingness to Accept: How Much Can They Differ?" *The American Economic Review* 81 (3): 635-47.

[7] Horowitz, J. K., and McConnell, K. E. 2003. "Willingness to Accept, Willingness to Pay and the Income Effect." *Journal of Economic Behavior and Organization* 51 (4): 537-45.

[8] Kling, R. W., Revier, C. F., and Sable, K. 2004. "Estimating the Public Good Value of Preserving a Local Historic Landmark: The Role of Non-substitutability and Citizen Information." *Urban Studies* 41 (10): 2025-41.

[9] Kopsidas, O., and Batzias, F. 2011. "Improvement of Urban Environment and Preservation of Cultural Heritage through Experimental Economics by a Modified Contingent Valuation Method (CVM)." *Recent Researches in Energy, Environment, Devices, Systems, Communications and Computers*: 157-62.

[10] Liao, T. F. 1994. *Interpreting Probability Models: Logit, Probit, and Other Generalized Linear Models*. London: Sage Publications Inc., 101.

[11] Menard, S. 2001. *Applied Logistic Regression Analysis (2nd ed.)*. London: Sage Publications Inc..

Journal of Environmental Science and Engineering A 7 (2018) 34-48
doi:10.17265/2162-5298/2018.01.005

What Kind of Development We Want to Afford Sustainable Living?

Kamaljit Kaur Sangha

Darwin Centre for Bushfire Research, Research Institute for the Environment and Livelihoods, Charles Darwin University, Darwin 0810, Australia

Abstract: The historical evidence is used to argue that the application of knowledge and modernization of the current economic and conservation approaches for directly relating to human dependence on nature are critical for advancing human well-being. Over the last ~50 years, despite our sound understanding of various ecological impacts at local, regional and global scales, we have largely failed to prevent decline in the health of natural systems worldwide. Our current approaches continue to promote utilitarian economy, focusing on materials. This paper advocates a shift from the current paradigms of economics and resource use, by proposing an ethical approach both to nature and economics, towards holistic development. The approach is based on peoples' well-being. It outlines how by integrating ethics, economy and nature, and finding simple solutions within the reach of public, sustainable development can become achievable much more efficiently and quickly than following our current lengthy and complex processes.

Key words: Nature, natural systems, ecosystem services, sustainable development, economics, human well-being.

1. Introduction

This paper offers a broad-scale integrated analysis of economy, society and nature's resources to emphasize the need for greater levels of realization and on-ground action at both the individual and societal level to achieve sustainable development. The modern economies are primarily focused on growth in materials, commonly perceived as development, as proven by rising GDP (Gross Domestic Product) which in contrast has failed to enhance people's life satisfaction [1]. With increasing choices, people always seem to want materials way beyond the necessities of life and spend a lot of time and energy in chasing them without realizing costs of their production or the pressure on natural resources. By linking human ethics with needs and economy, this paper aims to enhance our current understanding of development.

Good quality air, water and food are indispensable and irreplaceable to live, however, people seem to take them for granted in their daily lives. More than 50% of the world's population, living in urban and semi-urban centres, is largely disconnected from nature's raw resources that support major material needs [2]. Modern way of living, in isolation from nature's resources, makes us blind to our moral responsibility to look after nature.

Over the last 50 years or so, there has been an excessive increase in consumerism coupled with a reduction in the availability of natural resources. This exerts immense pressure on nature's resources which may well lead to severe social-economic mayhem [3, 4] for increasing levels of social inequality, exclusion and injustice, dampening development outcomes. We[1] are coming to realize that we must behave as responsible citizens of Mother Earth. The key questions are, firstly, *can* we, as individuals and society, do this, and secondly, do we have the *will* to do it?

Daly, H. E. [5] puts forth that the fundamental human morals 'Thankfulness' for good deeds, and

Corresponding author: Kamaljit Kaur Sangha, research fellow, research field: ecological economics.

[1] *We* or *us* refers to the people in general who use nature's resources, and return little of real value to nature.

'Repentance' for wrongdoings—common to all societies—have been forgotten for nature. People largely fail to be thankful for the basics of life—good air, water and food—and they seem to be unrepentant for exploiting nature's resources, and creating a huge amount of waste from what we discard.

We all need to revive our sense of care for the planet, our fellow human beings and other organisms with whom we share this planet. Because of our increasing disconnect from raw resources, we are forgetting our dependence on nature. The only exceptions are the agrarian and traditional societies whose livelihoods directly depend on nature or some eco-friendly people. This adage from the 14th Dalai Lama nicely frames the need for changing our current value systems and the use of natural resources: *Because we all share this planet earth, we have to learn to live in harmony and peace with each other and with nature. This is not just a dream, but a necessity* (The 14th Dalai Lama [6]); advocating a moral principle of care and share that we all need to embed in our daily living. Promoting human ethics for nature and linking them with economy can add value to the present scientific knowledge for realizing grass-root changes towards sustainable development.

To highlight the importance of the role of nature for human lives, two important frameworks have been developed to date. In 2003, the United Nations initiated the MA (Millennium Ecosystem Assessment)—the first global effort of its kind, which published several seminal reports demonstrating the links between nature's services and people's well-being (Fig. 1a) [7-12]. In 2012, the MA research was advanced by the IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services), connecting science with policy (Fig. 1b) [13]. To date, 127 nations are signatories to the IPBES. The platform particularly emphasizes the inclusion of nature's role in public policy through developing targeted policy documents and frameworks, to enhance human well-being and develop sustainable economies. However, none of these frameworks directly account for the natural resources in modern economy or challenge its ways. Indeed, our modern economy is an 'engineered economy' based on increasing choices of materials, while excluding or disregarding human ethics [14, 15]. Its progress is measured from GDP, completely ignoring nature's inputs to produce those products [1].

There is an immense amount of scientific knowledge available to researchers and policy makers, especially in ecological sciences including many databases, international conventions and organisations including NGOs (Non-Government Organisations) (Table 1). Additionally, there are state institutions, local organisations and departments dealing with environment related issues at the local and regional scales. But, despite all this available knowledge, organizational funds and support, policy instruments and modern technologies, earth's natural resources are degrading and declining faster than ever before [12]. For example, 30% of cropping land is experiencing high rates of degradation; > 50% of the area of six biomes has been converted to agriculture since the 1950s causing severe loss of forest cover; 20% of coral reefs and 35% of mangrove area has been lost, and > 30% increase in atmospheric CO_2 emissions has occurred since the 1750s.

The economic activity is identified, among other main drivers such as habitat change, over-exploitation, invasive alien species, pollution, climate change, population change, as the most critical driver causing above changes in the natural systems [12]. Our current levels of economic activity reflect human greed to obtain materials at the cost of nature's resources. As Daly (1996) says '*our ability and inclination to enrich the present at the expense of the future, and of other species, is as real and as sinful as our tendency to further enrich the wealthy at the expense of the poor*'.

The current tragic state of natural systems, as described by the MA [8], is a result of greed for materials and comforts, ignorance, negligence and the

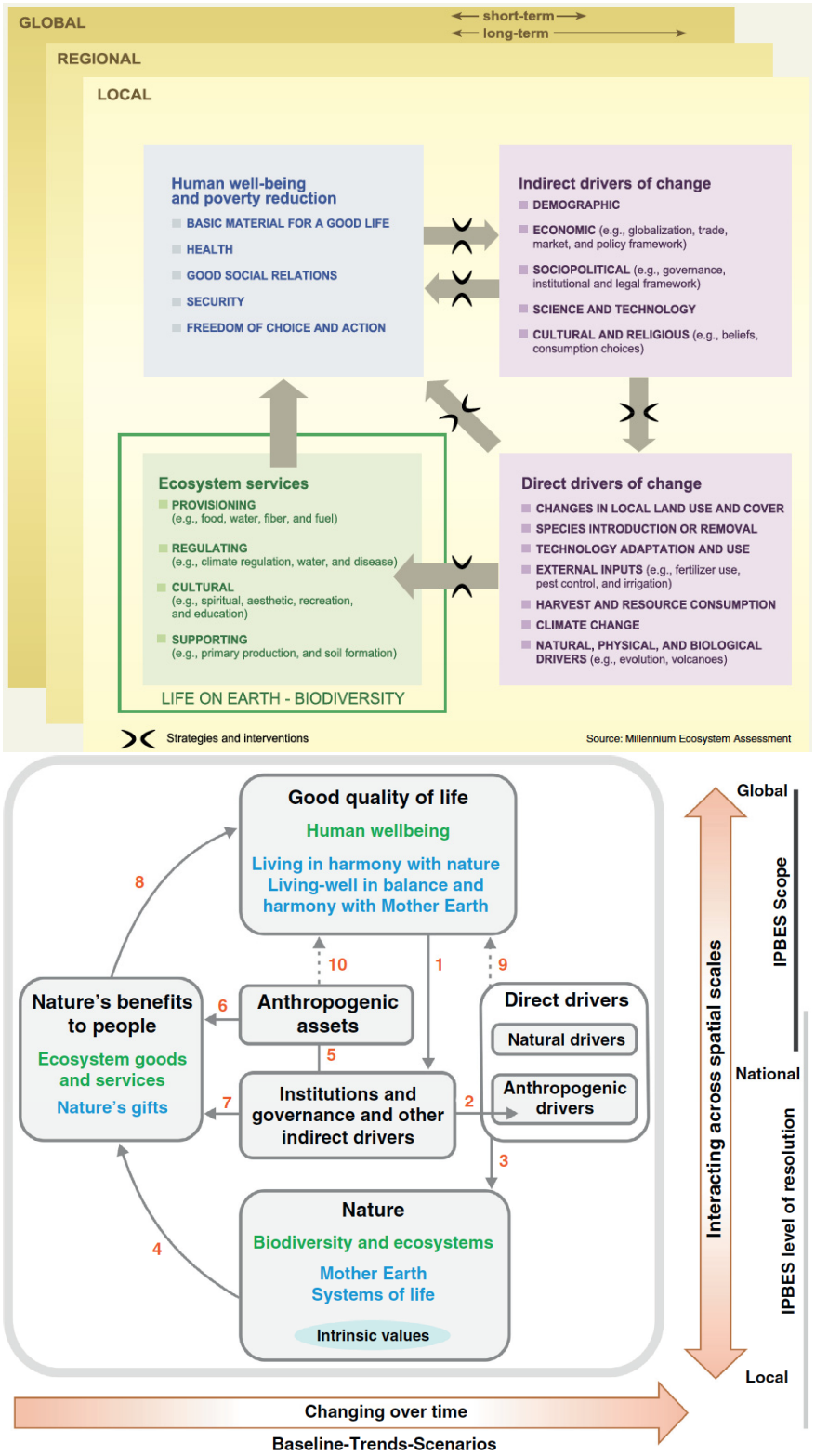


Fig. 1 The MA and IPBES frameworks.

a. The MA framework links human well-being and the ecosystem services (on the left-hand side), which are influenced through various direct and indirect drivers of change (on the right-hand side) [7].

b. IPBES framework offers six main elements: Nature, Nature's benefits, Good quality of life, Anthropogenic assets, Direct drivers and Institutions and governance. The arrows denote the links between elements, along with temporal and spatial scales (side arrows) [13].

Table 1 A snapshot of main scientific databases, major conventions and NGOs dealing with natural environment.

Databases	International conventions, organisations and NGOs
Web of Science supporting 256 disciplines with 12,000 journals, 50, 000 books and 160,000 conference proceedings.	Convention on Biological Diversity, signed by 168 countries, suggesting the importance of earth's biological resources towards humanity's economic and social development; IPCC (Intergovernmental Panel for Climate Change) recommending climate related policies; IUCN (International Union for Conservation of Nature and Natural Resources) guiding conservation policies; UN (United Nation)'s special ES related initiatives—MA and IPBES.
Science Direct supporting > 3,800 journals and 35,000 books.	UNEP (United Nations Environment Programme) assisting member states in implementing environmentally sound policies and practices; WRI (World Resources Institute); TEEB (The Economics of Ecosystems and Biodiversity); GEF (Global Environmental Facility); Global Development and Environmental Institute; International Institute for Environment and Development.
Scopus supporting > 22,000 journals and 34, 000 books, ~67 million records; PubMed about another 27 million records.	NGOs: Greenpeace; Friends of the Earth International; World Wide Fund for Nature; The Nature Conservancy.

parochial approach of modern economies. It seems we lack the *will* to change our utilitarian economic approach despite our awareness of the state and importance of nature's systems. Across the globe, the government policies largely fail to consider nature's benefits into decision-making despite many ecologists, conservationists, and even some economists advocating such an approach over the last few decades [16-23]. Moreover, various international, national and local initiatives have argued for including or underscoring nature's services into economic models.

On the contrary, the current economic models are perceived largely as pathways for development[2] i.e. growth [18] (in materials and choices for people). With increasing financial capacity, particularly the disposable income of people in the developing world, many more are becoming materialistic, thus exerting extensive pressure on nature [12, 24].

For the continued survival of human society, a sustainable scale of development is essential. It is development without growth (in materials). Sustainable development is the qualitative improvement of human quality of life, not the quantitative increase of materials, within nature's assimilative and regenerative capacities [5]. Our high levels of knowledge yet our lack of willingness to act begs the question—how can we realize the importance of nature and achieve sustainable development?

Based on literature and desktop analyses, this paper offers evidence of excessive resource use both in the past and present, followed by two suggested future scenarios. Then, it outlines three key approaches to help realize people's dependence on natural resources for sustainable development: applying an integrated economic approach to development focusing on people's well-being; embedding ethics in economic models and to conserve nature; learning lessons from Indigenous and local communities to live in harmony with nature. Overall, the paper aims to address the broad themes of economics, development, and conservation of nature, which are applicable to many developed and developing countries.

2. Historical Evidence of Resource Misuse: the Demise of Two Important Ancient Civilizations

It is difficult to determine definitive relationships between environmental and social changes because

[2] Development (non-italic) refers to usual perception as 'growth' whereas *development* (in italics) to sustainable development focusing on people's well-being. The word '*development*' is used because it's commonly applied in economics and suggests advancement/betterment; the need is to change its perception from advancement in materials—growth—to the advancement of human well-being.

each society responds in different ways at different times in a given set of socio-political circumstances. But, similarities between some ancient civilizations and the modern society on the usages of natural resources and related consequences are now becoming apparent, offering valuable lessons for the present and future generations.

Weiss, H. and Bradley, R. S. [25], de Menocal, P. B. [26] and Diamond, J. [27] pointed out that several civilizations from the prehistoric and early historic era suddenly collapsed primarily due to abrupt changes in climate. Particularly, prolonged droughts and increased temperatures affected food and water resources, thus impacting people's survival. We chose the Indus and Mayan, the key well-developed ancient civilizations, to demonstrate how their usage of natural resources impacted on their survival.

2.1 Indus Valley or Harappan Civilization

The Indus region, from north-east Afganistan to north-west India, flourished from ~9.5-3.3 ka BP [28]. The Indus people established a highly sophisticated urban culture, with their own 'Dravidian' script, well-developed houses, public and private wells, wide roads and underground drainage systems; proving to be one of the most extensive ancient civilization [28]. Mohenjo-daro, one of the excavation sites, is currently listed as a UNESCO world heritage site.

The floodplains of the Indus ('Sindhu' river in Sanskrit or Hindi) and Ghaggar (also known as 'Saraswati') rivers supported Indus civilization. Both rivers and their channels offered fertile soils for agriculture, and people mastered the art of growing a variety of crops such as wheat, barley, cotton, mustard and sesame. However, the waning of monsoons ~5-4 ka BP, coupled with large-scale droughts, led to changes in people's subsistence strategies. Particularly, these events caused reduced seed ubiquity and density of wheat and barley, which ultimately lessened food availability, and led to de-urbanisation and the slow decline of this great civilization [28, 29].

Among a number of factors including change in monsoon and river dynamics, socio-economic and political situations, the catastrophic floods and severe droughts that affected agricultural productivity and the availability of food resources, were the key triggering socio-political turmoil and ultimately the demise [25, 28]. It is thought highly likely that reduced agricultural productivity disrupted the Indus economy, making survival difficult for people, however, this requires further investigation (Ancient History Encyclopedia).

2.2 Mayan Civilization

The Mesoamerican, Mayan, civilization flourished from ~7-1 ka BP across central America. Concentrated in the central-lowland of Yucatan Peninsula, supporting tropical rainforests, the Mayans were highly resource-specialized who possessed significant infrastructure of engineered cities, water systems and managed landscapes. It was thought that the burning and clearing of forests for agriculture or setting orchards caused a severe decline in rainfall, consequently limited the availability of water [30]. Well-engineered water reservoirs could serve the people during short-dry spells, but not during long-dry spells. Instead, these reservoirs made people highly vulnerable, probably due to lack of people's adaptability to reduced water resources [31]. Over-and ill-use of forest and water resources, coupled with social and political complexities, appeared to cause the collapse of > 90% the Mayan civilization [30, 32, 33].

Despite being an engineered society, the Mayans could not escape the catastrophic environmental effects that permeated through their social, political, and cultural domains, and most likely led to their demise [30, 31].

There are several other agriculture-based civilizations who suffered similar demise. For example, the Mesopotamian civilization—a cultural and technological cradle of the Western world—farmed lands earlier fertile, later more marginal, stressing available soil and water resources

and creating a highly vulnerable system that ultimately resulted in ecological backlash and led to their demise [25]. 'Collapse' by Diamond [27] points out climate change and environmental problems, among several other factors, causing downfall of past civilizations while alerting modern societies.

Analogous to the ancient civilizations, our modern society faces the challenges of climate change, the uncertain and reduced availability of water and food resources due to droughts, floods, degradation of land, over exploitation of productive land and use of marginal land for agriculture, and excessive misuse of resources; suggesting a need to learn from the past, adapt and limit resource use, to sustainably use natural resources through careful planning for and acting towards the kind of development and economy we really want.

3. Contemporary Examples of Misuse or Over-exploitation of Resources

Local, regional and global assessments of natural systems, conducted by the MA [8-12] from 2000 to 2005 and IPBES assessments in 2017 (the catalogue of assessments), clearly demonstrate their fast decline over the last century. More than 50% of forestland has been converted for agriculture [12], yet we fail to attain global food security [24]. Instead, this conversion instigated high rates of species extinction [12]. Both terrestrial and marine systems are being over-used in meeting human needs. Consequently, human activities have caused land degradation, pollution, loss of biodiversity, and changes to climate [12, 24, 34-36], resulting in multi-fold socio-economic and ecological consequences, including increasing inequality both within and between the developed and developing world [24].

At this point, it is acknowledged that there are millions of regional, local and individual studies that highlight declining health of terrestrial, freshwater and marine systems across the world, which are not cited here.

The irony is that despite all the technological progress and extensive use of resources, we still fail to meet the basic need for food for the millions of the world's population who are under-nourished as indicated by the HDR (Human Development Reports) [37, 38] and the UN reports [24] (Fig. 2) [12].

There are a number of consequences of modern societies using and exploiting natural resources to develop and maximize economies. One of the main ones is the growing inequality among people in the developing and developed world over the past 20-30 years. So much so that we face social mayhem [3, 5, 14, 39-42]. For example, economic inequality is on the rise in most developed (OECD) countries. It is even more evident in nearly every developing country [3, 40]. As Keeley, B. [3] points out, "the gap between rich and poor is at its highest for the last 30 years, with the top 10% now earning 9.6 times more than the poorest 10%." Widening the income gap between the rich and poor, especially in the developing world, contributes to inequality in education, health and other social services, setting up unjust and unfair social systems [3, 40].

The following examples illustrate how maximizing economies at the expense of natural resources impact on people:

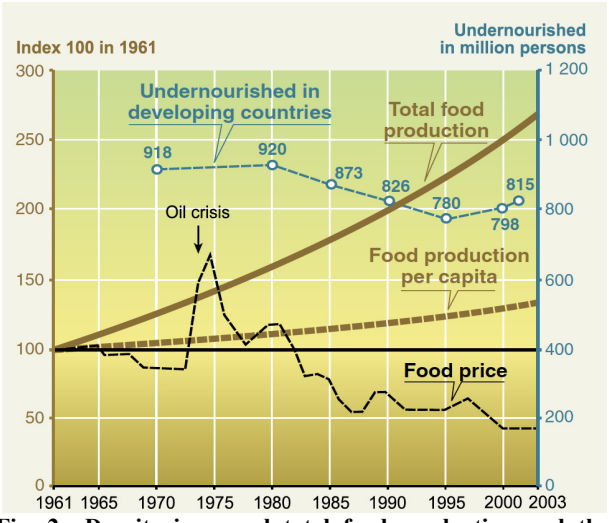


Fig. 2 Despite increased total food production and the large-scale conversion of forest into agriculture lands, the undernourished people are still high [12].

In the developing world, acquiring land for development has led to wide-scale displacement and upheaval of local and Indigenous communities within and between nations [43]. For example, in China, the National Research Center for Resettlement noted that over 45 million people were displaced by development projects between 1950 and 2000 [44]. In India, dam projects alone displaced up to 40 million people [45]. Moreover, land grab by multinational or influential investors for development purposes has compromised the interests and livelihoods of millions of poor people, causing grievances and conflict in many countries across Africa and Asia [46]. The current refugee migration from the Middle-East and Asia can be partially attributed to a lack of locally relevant development with little fair and equal work opportunities, thus social upheaval and suffering that contributes to political unrest we face today [4, 39]. Millions of people are leaving their homelands for various reasons, and the trend is increasingly alarming across the developing world.

Ultimately, coupled with environmental calamities, unfair social systems can result in multi-fold socioeconomic-political problems as evidenced by inequality, injustice, and violence—including terrorism at various local, regional and global scales [4, 18]. The Secretary-General of the OECD, Angel Gurría, warned that "high levels of inequality generate high costs for society, dampening social mobility, undermining the labour market prospects of vulnerable social groups, and creating social unrest" [3]. The consequences of modern economic development focusing on large scale investments and monetary returns while imperiling the livelihoods of world's rural populations are socially, environmentally and politically devastating.

4. Applying Two Basic Scenarios to Scope Our *Well-being*

All human beings, whether in the developed or developing world, want to live well and lead a meaningful life. To reflect this, the concept of human well-being, that is 'a state of being comfortable, healthy, or happy', is very useful [5, 15, 18, 20, 21, 47-49]; in contrast to commonly applied measure, GDP, of development or growth (in materials).

The MA [7] considered five constituents of human well-being: the basic materials for life; good health; security; social relations; and freedom and choice. A certain level of economic choices and opportunities are necessary to support life, but more beyond that does not produce greater satisfaction.

Two basic scenarios are applied: BAU (Business As Usual) and LHN (Living in Harmony with Nature), to scope human well-being. The data to measure human well-being is based on various global, regional and local studies, including several reports by the HDR [37, 38], IPBES (catalogue of assessments [13]), IPCC [35], MA [7-12], WRI [36, 49] and the UN [24]. This simplistic analysis aims to show the status of human well-being in 20 or 50 years time were we to continue to live as we do today (Table 2).

To continue benefiting from nature in the future, each one of us needs to realize our dependence on, and embrace a way of life that is in harmony with, nature [50]. As HDR [37] suggests, the world should focus more on sustainable work that doesn't put people at risk. But, how do we realize our dependence on nature? And second, how can we change our current approaches to development, economy and nature?

5. Realizing our Dependence on Nature and Transforming Our Current Approaches to Development

Re-visiting our past (fate of ancient civilizations), scenario planning (wise future thinking), applying integrated and ethical economic approaches, and learning from Indigenous and local communities to live in harmony with nature (as discussed below) can all help us transform our current approaches to achieve sustainable *development* and better care for nature.

Table 2 Trends in our well-being under BAU and LHN scenarios in 20 and 50 years time (acknowledging scientific and technical advances).

Well-being constituents	BAU		LHN	
	20 years	50 years	20 years	50 years
Basic materials for life	↖	↓	↖	↑
Good health	↖	↓	↖	↑
Security	↖	↓	↖	↑
Social relations	↖↓	↓↖	↖	↑
Freedom and choice	↖↓	↓	↖	↑

↓ - denotes a decline; ↖ - low improvement; ↑ - good improvement; ↖ - modest improvement.

Our notion of development in this paper is about improving the quality of life, i.e. well-being. From now on, we use the term *development* (italicized) for *human well-being*. This paper looks at *development* not only from an economic perspective but also from ecological and social perspectives.

There is need to mine the immense *silos* that exist of ecological, social and economic knowledges, but more importantly, an urgent need is to bridge the gap between these *silos* (disciplines). Bridging the knowledge gap is a major important difference between Indigenous/local and modern, largely urban, societies. The former's knowledge is gained, integrated, and practised through customs and traditions, whereas the latter's knowledge, though extensive, is typically formally acquired and not always integrated. This difference is clearly evident in how people live in rural and remote places because they depend on nature for their day-to-day living in contrast to urban or semi-urban people who are formally educated but often less knowledgable about nature's service despite their greater dependence on, and need for materials to support their way of life. The urban society comprises > 50% of the world's population, with > 70% in the developed world [2]. Commonly, the urbanites (knowledge acquirers) have a greater say in policy decision-making, irrespective of regional or national boundaries, whereas Indigenous/local peoples (practitioners) have very little say. Thus, it becomes very difficult to change modern society's pattern of excessive consumerism, associated resource-use and indifference to nature. This paper, based on synthesis of knowledge from various resources, suggests three pathways to move towards sustainable *development*.

5.1 Inclusive and Integrated Economic Approaches to Development

An integrated, modernized concept of *development*—focusing on peoples' well-being enabling them to lead their lives as they want—is essential, as advocated by Costanza, R., et al. [1] and Sen, A. [15, 48]. But, to facilitate this, some key reforms are required. Firstly, we need a new vision for *development* that focuses on enabling people, i.e. enhancing capabilities, freedoms and rights, and better social justice through offering appropriate opportunities, as suggested by Sen, A. [15]. Secondly, *development* needs to be linked with the supplier of fundamental services that support people's living, i.e. nature, by incorporating efficient allocation, sustainable scale and fair distribution of nature's resources [5]. Blending *development* and use of natural resources at a sustainable scale can help us develop the ideal integrated framework to improve both human well-being and the state of nature's resources which support well-being.

A simple integrated model of *development* focusing on people's well-being and nature is illustrated in Fig. 3. Nature is shown as the basis for supporting the socioeconomic and cultural fabric of households and businesses. The model shows the importance of

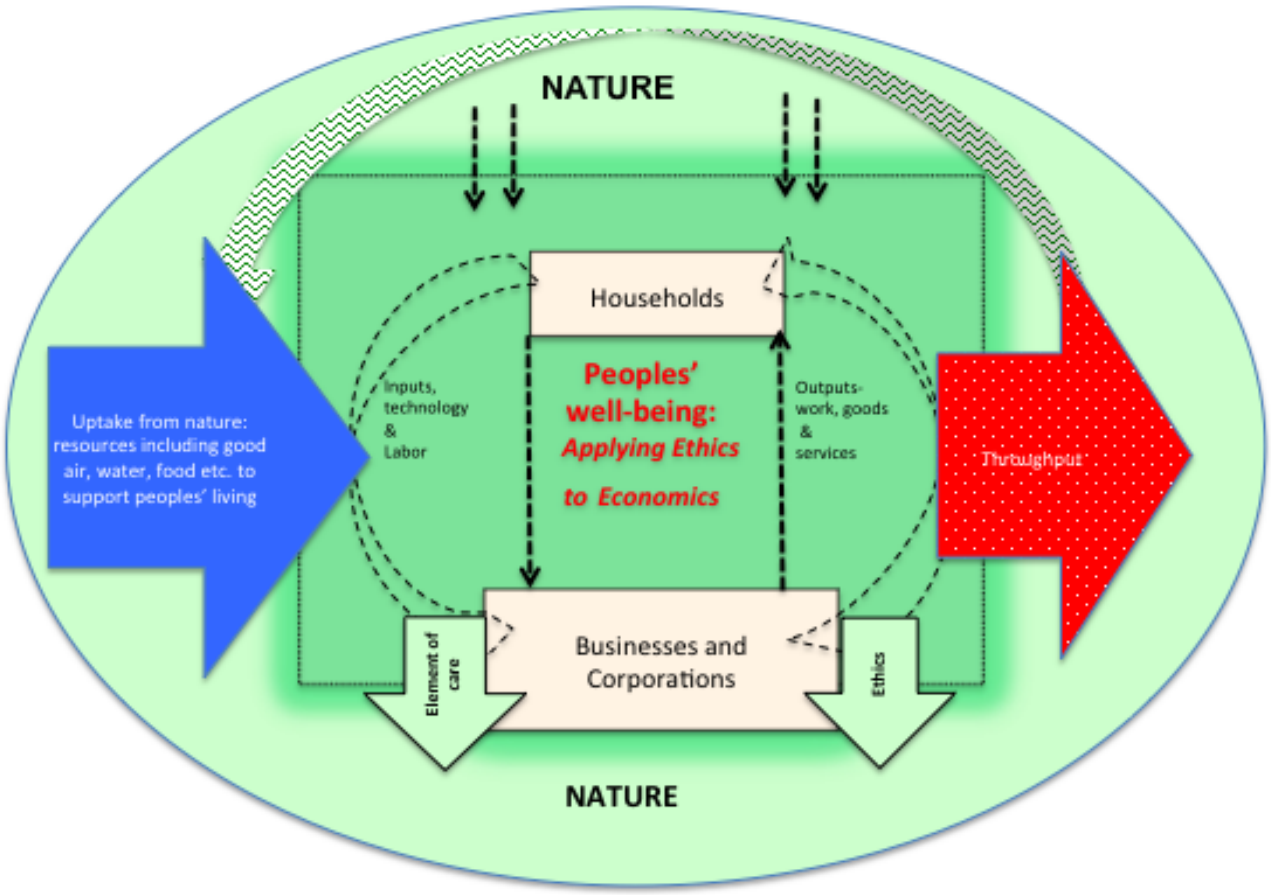


Fig. 3 An integrated model for well-being focused *development*.

continual flows (goods and services) from nature to human well-being. To sustain these flows, the waste (the throughput including recycled materials that also require energy and resources) needs to be matched with the carrying capacity of nature's systems [5]. At each individual business and household level, a balanced uptake from, and throughput to, nature becomes an integral part of the total economic activity, i.e. input and output in order to operate at a sustainable, efficient, equitable scale to enhance human well-being. Most importantly, this model emphasizes integrating ethical principles with economic activity to achieve *development*. However, this kind of *development* requires wise policy support and recognition. It also needs the policy makers and the public to think of *development* as supporting peoples' capabilities, rights and freedoms and opportunities for employment, beyond simply material needs, while still valuing, caring and accounting for the natural environment.

Nature supports human well-being, yet only households and businesses and corporations outputs represent the state of development. For sustainable development, uptake and throughput (waste) needs to meet the local ecosystems capacities with a focus on peoples' well-being applying ethics to nature and economics (inner dark green glowing box indicates origin of raw resources from nature that support development).

5.2 Advancing Human Ethics to Economy and Nature

Limiting our needs to the necessary materials for affording sustainable living and applying integrated knowledges to manage and improve natural systems that supply those materials, is a much-needed approach [51, 52]. To do so, a radical change for how

we value materials and nature is absolutely required. As the 14th Dalai Lama says, *"Human happiness and human satisfaction must ultimately come from within oneself. It is wrong to expect some final satisfaction to come from money* (materials) *or from a computer."* Satisfaction for materials '*fulfillment or gratification*, *just the right amount—lagom* (in Swedish) or *contentment—Santushti* (in Hindi)' is a key element of human ethics that can prove useful in transforming the paradigms of *development* and valuing nature, but how do we seek it?

Satisfaction or the *feeling of being well and contented* is linked to spirituality [53]. Spirituality, irrespective of religious beliefs, is a vital aspect of human life allowing to constantly explore the meaning of our lives and to improve ourselves. Nature offers us this exceptional service and delivers multitude benefits such as health, resilience, compassion, self-esteem and equitability. Spiritual experiences help us to habitually meditate on the entire vista and the main purpose of our living while evoking the end of life. Consequently, this day-to-day realization can make us to be wise for material needs and usage, and to inculcate moral responsibility to look after nature.

Many local and Indigenous people protect and respect nature's components because of instilled spiritual beliefs, cultural practices, norms and customs. Due to these ethics, several developing countries, despite high population, support rich biodiversity because of reduced per capita use of resources in contrast to the developed world where its ~10 folds than the former [24]. For example, the state of Uttar Pradesh in India is highly dense, 828 person/km^2, but supports the highest diversity of cranes due to people's ethos not to kill cranes (no government regulation); instead people leave some feed for cranes in their rice fields despite being poor and under-developed [54, 55].

Additionally, our isolation from raw resources, which are required to produce goods and materials, is one of the main reasons for our failure today to comprehend nature's role in our lives, in addition to increased accessibility and transportation of processed materials at the costs to the environment. Inculcating right moral or spiritual values can make us envisage ourselves as part of nature, rather than separate from nature. We need to adopt simple but active attitudes towards solving common environmental problems that help resolve our addictions for goods and materials [51]. Our current local, regional, and global socio-political and environmental situations beckon a mass cross-border radical movement to save 'our home' by inculcating a sense of 'satisfaction' for material needs and practising right ethics.

5.3 Learning from Exceptional Local and Indigenous Populations Surviving to Date and Applying Knowledges

Many local and Indigenous people across the globe live in harmony with nature through their cultural norms and practices, such as addressing nature as 'Mother' and the biodiversity components as parts of nature [56, 57].

Indigenous people in Australia are testament to such a philosophy for continuing to survive on a dry continent for the last > 50,000 BP [58]. People, through experiences, have unique socio-economic, cultural and emotional relationships with their land and sea systems [59-61], and they treat their land, '*country*', as a living entity [61, 62].

Many traditional agrarian societies, in particular, depend on nature and use resources judiciously understanding the value for their sustenance, and have developed their specific customs suiting local conditions. Such indigenous and local views can guide the modern societies to live in harmony with nature. Unarguably, although our modern lifestyles are much more dependent on nature than the traditional lifestyles for simply demanding more materials, we grossly fail to realize or act to sustain the use of nature's resources.

6. How to Achieve Sustainable and Well-being Focused *Development*?—A Way Forward

It is a compelling time to find, invest and implement solutions to maintain the flow of nature's services (ES) for human well-being, especially realizing the fate of our ancient civilizations. There is a need to share and implement holistic, systems solutions, in partnership with the locals, applying individual and collective efforts, across the world. To achieve sustainable *development*, the current socio-economic and political systems require modernization, some outlined below:

Integrated economies focusing on people's well-being: our current GDP-based economies require a radical transformation to embrace the critical role of nature for supporting humankind [1, 5]. Our future economies should focus on improving individual as well as societal well-being through better human rights and freedom, justice and social systems, fair distribution of resources and access to services, enhancing peoples' capabilities while offering them appropriate and equitable opportunities [14, 15, 48].

Development: there is need to understand and apply a holistic meaning of '*development'* beyond increasing choices or materials, for enhancing people's quality of life [15, 47, 48]. This kind of *development* should recognize and reward the local and Indigenous people who live in harmony with nature and contribute towards ES flows for the greater humankind, promoting equitable *development*.

Public awareness: there is adequate scientific and local knowledge demonstrating how climate change, land degradation, over-use of resources, and pollution of land, water and air affect peoples' well-being across the world. The nations, NGOs, and local agencies including educational institutions need to better communicate with the public in simple non-scientific, but in interactive and coherent ways by directly relating the environmental impacts to people's well-being. Currently, the IPBES is focusing on bridging the gap between science and policy [13], whereas an equal or more compelling is to connectwith, and raise awarenessamo, whereas an equal or more compelling is to connect with, and raise awareness among, the public to change opulent lifestyles particularly in the developed world, and achieve solution-based outcomes.

Action-based approaches: at the government level, there is a need to recognize, support and invest in solution-based approaches that promote sustainable development, including the 'action'-based changes that are brought by many local groups, NGOs and individuals at the local, regional and global scale. Some examples include community conservation efforts—http://www.communityconservation.net/community-stories/; Satoyama in Japan—http://topdocumentaryfilms.com/satoyama/; Auroville—a universal township in India, with ~50,000 people from 49 Nations around the world live in harmony with nature (http://www.auroville.org); Environmental activists such as Jadav Payeng planting 550 ha of barren land (http://www.jadavpayeng.org/home); many Eco-villages around the world (https://theecovillage.com.au, http://www.earthaven.org and http://www.ic.org/directory/ecovillages/); and many industrial and residential buildings using green technologies and energy sources.

There is a need to spread such stories around the world, and to commence a mass movement demonstrating how living in harmony with nature (as was proclaimed by the UN's General Assembly in 2011) is a real possibility that can enhance people's well-being.

Ethical and moral values: Incorporating right ethos into our day-to-day living, economy, policies, education and decision-making processes can play a significant role in how the public and corporates value and manage nature. Sen, A. [14] strongly advocates

for linking ethics and economics to enrich our philosophy of living to deliver better socio-economic and environmental outcomes.

A key principle of applying 'contentment or satisfaction' and re-focusing policies on enhancing the quality of life is to help reduce the use of resources while improving human well-being. However, this demands a profound shift in our current thinking and policy decision-making.

Equity: equitable distribution of natural and social benefits and costs across the spatial—local, regional and global—and temporal—present and future—scales to minimize the differential in people's quality of life that may exist among various ethnic or gender groups of a state or even among the states will help promote societal well-being in the global community, with better harmony as well as environmental outcomes, while evading socio-political conflicts. Moreover, it will further minimize the social, health or justice system costs.

Accounting for the natural-cultural losses/gains: annual assessments of loss of natural assets, cultural landscapes, nature-based socio-cultural and economic activities, and languages at the local and regional scales over time can raise awareness among the public and policy decision-makers for what is gained or lost over time in the name of development.

7. Discussion

Looking at the past and declining current state of natural systems (7-12), there is a need to develop integrated sustainable strategies across the nations, both at the public and policy levels. Sustainable strategies that focus on people's well-being while recognizing and respecting local differences. Importantly, ancient Hindu, Jain, Sikh and Buddhist scripts and Indigenous cultures directly emphasize on nature being Divine '*Vashudhaiva Katumbkam'*—community of all beings on earth including plants and animals, 'Mother' or earth as sacred, '*Bhumi Ma'*, and guide humanity to limit material needs to achieve satisfying and unifying levels of living.

For transforming modern economies to support well-being focused *development*, understanding the value (importance) of nature, the nature of 'value' for enhancing human well-being, and rural (non-marketable) economies is imperative to avert adverse socio-economic, ecological and political consequences that has happened a few times in human history causing the demise of civilizations or uprooting rural populations [25, 27]. The proposed transformations, discussed in the previous section, require institutional, political and governance support for designing appropriate strategies. A political will to support change, and embrace the idea of integrated living—for an efficient, equitable and sustainable economy that operates within the limits of nature's capacity, along with locally appropriate, non-partisan, bottom-up (polycentric) governance and institutional structures is vital. These transformative initiatives require substantial national and international cooperation, otherwise, as Shiva, V. [4] says, we are likely to witness unprecedented environmental, political and social disruptions that will impact on all of us, irrespective of our borderlines.

International platforms such as IPCC and IPBES (and earlier the MA) continue to conduct regional and global assessments for informing policy makers. Various local and inter-state agencies continue to invest in looking at the problems and developing guidelines, frameworks, conventions and other policy instruments. However, the relevance of high-level policy decisions to on-ground actions or change is likely to be dubious until local people are empowered and fairly involved in decision-making processes. In fact, the current policy approaches and related instruments should be equally complemented with direct incentives for people who contribute towards greater societal and nature's benefits. Direct and simple actions improving nature's services for peoples' well-being can offer effective and quick outcomes

compared to the complex modern policy approaches that hardly reach the public.

Applying and advocating an ethical approach to economy and nature, considering socio-ecological and economic connections, re-focusing *development* on human well-being, and encouraging people to become the practitioners to live in harmony with nature, we will be able to fulfil our responsibility towards nature without remorse for exploiting nature's systems.

References

[1] Costanza, R., Kubiszewski, I., Giovannini, E., Lovins, H., McGlade, J., Pickett, K. E., et al. 2014. "Development: Time to Leave GDP Behind." *Nature* 505: 283-5.

[2] Guerry, A. D., Polasky, S., Lubchenco, J., Chaplin-Kramer, R., Daily, G. C., Griffin, R., et al. 2015. "Natural Capital and Ecosystem Services Informing Decisions: From Promise to Practice." *Proceedings of the National Academy of Sciences* 112: 7348-55.

[3] Keeley, B. 2015. *Income Inequality: The Gap between Rich and Poor, OECD Insights*. Paris: OECD Publishing. Accessed Feb 8, 2018. http://dx.doi.org/10.1787/9789264246010-en.

[4] Shiva, V. 2016. *Earth Democracy: Justice, Sustainability and Peace*. London, UK: ZED Books Ltd..

[5] Daly, H. E. 1996. *Beyond Growth: The Economics of Sustainable Development*. Beacon Press.

[6] The 14th Dalai Lama (Tenzin Gyatso) and Norman, A. 1999. *Ancient Wisdom, Modern World: Ethics for the New Millennium.* United Kingdom: Little, Brown Company.

[7] MA (Millennium Ecosystem Assessment). 2003. *Ecosystems and Human Well-being: A Framework for Assessment.* Washington, D.C.: Island Press.

[8] MA. 2005a. "Ecosystems and Human Well-being: Current State and Trends." In *Findings of the Current State and Trends Working Group*, edited by Hussan, R., Scholes, R., and Ash, N. Island Press, 917.

[9] MA. 2005b. "Ecosystems and Human Well-being: Scenarios." In *Findings of the Scenarios Working Group*, edited by Carpenter, S. R., Pingali, P., Bennett, E., and Zurek, M. B. Island Press, 560.

[10] MA. 2005c. "Ecosystems and Human Well-being: Policy Responses." In *Findings of the Responses Working Group*, edited by Chopra, K., Leemans, R., Kumar, P., and Simons, H. Island Press, 621.

[11] MA. 2005d. "Ecosystems and Human Well-being: Multiple Assessments." In *Findings of the Multiple Assessments Working Group*, edited by Capistrano, D., Samper, K. C., Lee, M. J., and Raudsepp-Hearne, C. Island Press, 388.

[12] MA. 2005e. *Ecosystems and Human Well-being: Synthesis*. Washington, DC: Island Press.

[13] IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). 2017. IPBES. Accessed June 1, 2017. http://www.ipbes.net.

[14] Sen, A. 1989. *On Ethics and Economics*. Wiley-Blackwell Publishers.

[15] Sen, A. 1999. *Commodities and Capabilities*. Oxford University Press.

[16] Costanza, R., d'Arge, R., de Groot, R., Farber, S., Grasso, M., Hannon, B., et al. 1997. "The Value of the World's Ecosystem Services and Natural Capital." *Nature* 387: 253-60.

[17] Daily, G. C., Söderqvist, T., Aniyar, S., Arrow, K., Dasgupta, P., Ehrlich, P. R., et al. 2000. "The Value of Nature and the Nature of Value." *Science* 289: 395-6.

[18] Daly, H. E. 2013. "A Further Critique of Growth Economics." *Ecological Economics* 88: 20-4.

[19] Daly, H. E. 1973. *Toward a Steady State Economy*. San Francisco: Freeman.

[20] Dasgupta, P. 2004. *Human Well Being and the Natural Environment* (second edition). Oxford University Press.

[21] Dasgupta, P. 2010. "Nature's Role in Sustaining Economic Development." *Philosophical Transactions of the Royal Society B: Biological Sciences* 365: 5-11.

[22] de Groot, R., Brander, L., van der Ploeg, S., Costanza, R., Bernard, F., Braat, L., et al. 2012. "Global Estimates of the Value of Ecosystems and Their Services in Monetary Units." *Ecosystem Services* 1: 50-61.

[23] IPBES (Intergovernmental Platform on Biodiversity and Ecosystem Services). 2016. *Summary for Policymakers of the Methodological Assessment of Scenarios and Models of Biodiversity and Ecosystem Services.* IPBES, 36.

[24] United Nations. 2016. *The Sustainable Development Goals Report 2016*. United Nations, New York, USA.

[25] Weiss, H., and Bradley, R. S. 2001. "What Drives Societal Collapse?" *Science* 291: 609-10.

[26] de Menocal, P. B. 2001. "Cultural Responses to Climate Change During the Late Holocene." *Science* 292: 667-73.

[27] Diamond, J. 2005. *Collapse: How Societies Choose to Fail or Succeed.* USA: Viking Press.

[28] Sarkar, A., Mukherjee, A. D., Bera, M. K., Das, B., Juyal, N., Morthekai, P., et al. 2016. "Oxygen Isotope in Archaeological Bioapatites from India: Implications to Climate Change and Decline of Bronze Age Harappan Civilization." *Scientific Reports* 6: 26555.

[29] Redman, C. L. 1999. *Human Impact on Ancient Environment.* Tuscon: University of Arizona Press.

[30] Turner, B. L., and Sabloff, J. A. 2012. "Classic Period Collapse of the Central Maya Lowlands: Insights about

Human-environment Relationships for Sustainability." *Proceedings of the National Academy of Sciences* 109: 13908-14.

[31] Kuil, L., Carr, G., Viglione, A., Prskawetz, A., and Blöschl, G. 2016. "Conceptualizing Socio-hydrological Drought Processes: The Case of the Maya Collapse." *Water Resources Research* 52: 6222-42.

[32] Redman, C. L., Crumley, C. L., Hassan, F. A., Hole, F., Morais, J., Riedel, F., et al. 2007. "Group Report: Millennial Perspectives on the Dynamic Interaction of Climate, People, and Resources (Chapter 9)." In *Sustainability or Collapse? An Integrated History and Future of eople on Earth*, edited by Costanza, R., Graumlich, L. J., and Steffen, W. Cambridge, Massachusetts: The MIT Press in Cooperation with Dahlem University Press , 115-50.

[33] Scarborough, V. L. 2007. "The Rise and Fall of the Ancient Maya: A Case Study in Political Ecology (Chapter 4)." In *Sustainability or Collapse? An Integrated History and Future of People on Earth*, edited by Costanza, R., Graumlich, L. J., and Steffen, W. Cambridge, Massachusetts: The MIT Press in cooperation with Dahlem University Press, 51-60.

[34] The ELD (Economics of Land Degradation) Initiative. 2015. *The Value of Land: Prosperous Lands and Positive Rewards through Sustainable Land Management.* Bonn, Germany: ELD Secretariat. Accessed March 12, 2018. http://www.eld-initiative.org.

[35] IPCC (Intergovernmental Panel on Climate Change). 2014. *Climate Change 2014: Synthesis Report.* Fifth Assessment report of the Intergovernmental Panel on Climate Change.

[36] WRI (World Resources Institute). 2017. "Various Reports and Projects on Ecosystem Services." Accessed January-June 2017. http://www.wri.org.

[37] HDR (Human Development Report). 2016. *Human Development for Everyone. The United Nations Development Programme (UNDP).* New York, USA: UN.

[38] HDR. 2015. *Work for Human Development. United Nations Development Programme.* New York, USA: UN.

[39] Humphreys, M. 2003. "Economics and Violent Conflict." Accessed June 15, 2017. http://www.preventconflict.org/portal/economics.

[40] OECD (Organisation for Economic Co-operation and Development). 2017. "Income Inequality" OECD. accessed April-July 2017. https://data.oecd.org/inequality/income-inequality.htm.

[41] OECD (Organisation for Economic Co-operation and Development). 2008. *Growing Unequal? Income Distribution and Poverty in OECD Countries*. Paris: OECD Publishing. Accessed January 10, 2018. http://dx.doi.org/10.1787/9789264044197-en.

[42] Shiva, V. 2013. *Making Peace with the Earth*. London, UK: Pluto Press.

[43] Duchicela, L. F., Jensby, S., Uquillas, J., Lukic, J., and Sirker, K. 2015. *Indigenous Peoples Development in World Bank Financed Projects: Our People, Our Resources. Striving for a Peaceful and Plentiful Planet.* Case studies report for the World Bank Group.

[44] Fuggle, R., and Smith, W. T. 2000. "Experience with Dams in Water and Energy Resource Development in the People's Republic of China." Country Review Paper Prepared for the World Commission on Dams, Cape Town, South Africa. Hydrosult Canada Inc., and Androdev Canada Inc. Accessed March 20, 2018. http://www.dams.org/kbase/studies/cn/.

[45] Taneja, B., and Thakkar, H. 2000. "Large Dams and Displacement in India. Submission no. SOC166 to the World Commission on Dams, 2000." Accessed March 2, 2018. http://www.dams.org/kbase/submissions/showsub.php?rec=SOC166.

[46] Krieger T., and Leroch, M. 2016. "The Political Economy of Land Grabbing." *Homo Oeconomicus* 33: 197-204.

[47] Costanza, R., Fisher, B., Ali, S., Beer, C., Bond, L., Boumans, R., et al. 2007. "Quality of Life: An Approach Integrating Opportunities, Human Needs, and Subjective Well-being." *Ecological Economics* 61: 267-76.

[48] Sen, A. 1999. *Development as Freedom*. Oxford University Press.

[49] World Resources 2000-2001. *A Guide to World Resources 2000-2001: People and Ecosystems: The Fraying Web of Life.* Washington, DC: World Resources Institute.

[50] United Nations. 2011. *Sustainable Development—Harmony with Nature*. UN General Assembly report (A/66/302) of General Assembly 66th Session.

[51] Costanza, R., Atkins, P. B. W., Bolton, M., Cork, S., Grigg, N. J., Kasser, T., et al. 2017. "Overcoming Societal Addictions: What can We Learn from Individual Therapies?" *Ecological Economics* 131: 543-50.

[52] Vemuri, A.W., and Costanza, R. 2006. "The Role of Human, Social, Built and Natural Capital in Explaining Life Satisfaction at the Country Level: Toward a National Well-Being Index (NWI)." *Ecological Economics* 58: 119-33.

[53] Frisch, M. 2006. Q*uality of Life Therapy: Applying a Life Satisfaction Approach to Positive Psychology and Cognitive Therapy.* NJ, USA: John Wiley & Sons, Inc..

[54] Sundar, K. S. G. 2008. "Uttar Pradesh: An Unlikely Shangri-La." *International Crane Foundation Bugle* 34: 6.

[55] Sundar, K. S. G., and Choudhury, B. C. 2003. "The

Indian Sarus Crane *Grus antigone*: A Literature Review." *Journal of Ecological Society* 16: 16-41.

[56] Posey, D., and Oxford Centre for the Environment Ethics and Society. 1999. "Cultural and Spiritual Values of Biodiversity." London and Nairobi: Intermediate Technology Publications and UN Environment Programme.

[57] Sangha, K. K., and Russell-Smith, J. 2017. "Towards an Indigenous Well-being Framework: An Australian example." *Conservation and Society* 15: 255-69.

[58] Rasmussen, M., Guo, X., Wang, Y., Lohmueller, K. E., Rasmussen, S., Albrechtsen, A., et al. 2011. "An Aboriginal Australian Genome Reveals Separate Human Dispersals into Asia." *Science* 334: 94-8.

[59] Edwards, W. H. 1988. *An Introduction to Aboriginal Societies*. Australia: Social Science Press.

[60] Grieves, V. 2009. *Aboriginal Spirituality: Aboriginal Philosophy. The Basis of Aboriginal Social and Emotional Wellbeing*. Darwin: Cooperative Research Centre for Aboriginal Health.

[61] Sangha, K. K., Russell-Smith, J., Morrison, S. C., Costanza, R., and Edwards, A. 2017. "Challenges for Valuing Ecosystem Services from an Indigenous Estate in Northern Australia." *Ecosystem Services* 25: 167-78.

[62] Sangha, K. K. 2015. *Ways to Live in Harmony with Nature*. Docklands: JoJo Publishing, Classic Author and Publishing Services Pty Ltd., 3008.

Journal of Environmental Science and Engineering A
Volume 7, Number 1, January 2018
David Publishing Company
616 Corporate Way, Suite 2-4876, Valley Cottage, NY 10989, USA
Tel: 1-323-984-7526, 323-410-1082; Fax: 1-323-984-7374, 323-908-0457
http://www.davidpublisher.com, www.davidpublisher.org
environmental@davidpublishing.org, environmental@davidpublishing.com